UNITED STATES DEPARTMENT OF AGRICULTURE

WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1922

PREPARED BY THE
OFFICE OF EXPERIMENT STATIONS

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1924

OFFICE OF EXPERIMENT STATIONS

E. W. ALLEN, Chief

RELATIONS WITH INSTITUTIONS FOR AGRICULTURAL RESEARCH

Supervision of Work and Expenditures of the State Experiment Stations under Federal Appropriations

E. W. ALLEN, E. R. FLINT, J. I. SCHULTE, W. H. EVANS, W. H. BEAL

EXPERIMENT STATION RECORD

E. W. ALLEN, Ph. D., editor; H. L. KNIGHT, B. S., associate editor; SYBIL L. SMITH, M. A., agricultural chemistry and agrotechny; W. H. BEAL, A. B., M. E., meteorology; R. W. TRULLINGER, B. S. C. E., soils and fertilizers; W. H. EVANS, Ph. D., and W. E. BOYD, Ph. B., agricultural botany and plant pathology; H. M. STEECE, B. S., field crops; J. W. WELLINGTON, B. S. horticulture and forestry; W. A. HOOKER, B. S., D. V. M., economic zoology and entomology; SYBIL L. SMITH, M. A., C. F. LANGWORTHY, Ph. D., D. Sc., foods and human nutrition; G. HAINES, M. S., animal husbandry, dairying, and dairy farming; W. A. HOOKER, B. S., D. V. M., and SYBIL L. SMITH, M. A., veterinary medicine; R. W. TRULLINGER, B. S. C. E., rural engineering; LOUISE MARBUT, A. B., rural economics, sociology, and agricultural education; MARTHA C. GUNDLACH, A. B., indexing; WILLIAM HENRY, proof reading.

With the cooperation of W. H. BEAL, in soils and fertilizers, E. MERRITT in rural economics and sociology, and E. H. SHINN in agricultural education.

DIVISION OF INSULAR STATIONS

W. H. EVANS, Ph. D., Chief

Alaska Experiment Stations

C. C. GEORGESON, M. S., D. Sc., agronomist in charge, Sitka; G. W. GASSER, B. S., assistant in charge, Fairbanks; C. S. HAHN, B. S., M. F., assistant in charge, Rampart; B. L. SCHNEIDER, B. S., assistant in charge, Matanuska; W. T. WHITE, B. S., assistant in charge, Kodiak.

Guam Experiment Station

C. W. EDWARDS, B. S., animal husbandman in charge, Island of Guam; ——— ———, agronomist and horticulturist; ——— ———, assistant in agronomy and extension work; J. GUERRERO, assistant in horticulture; F. P. LEON GUERRERO, assistant in animal husbandry; P. NELSON, assistant.

Hawaii Experiment Station

J. M. WESTGATE, M. S., agronomist in charge, Honolulu; W. T. POPE, M. S., horticulturist; ——— ———, superintendent of extension work; R. A. GOFF, B. S., extension agent, Hilo; H. L. CHUNG, M. S., agronomist; J. C. RIPPERTON, assistant chemist; Mrs. NELLIE A. RUSSELL, assistant in domestic science.

Porto Rico Experiment Station

D. W. MAY, M. Agr., agronomist in charge, Mayaguez; T. B. MCCLELLAND, A. B., horticulturist; W. V. TOWER, B. S., entomologist; L. G. WILLIS, B. S., chemist; THOMAS BREGGER, B. S., plant breeder; J. O. CARRERO, B. S. Ch. E., assistant chemist; W. P. SNYDER, B. S., assistant in plant breeding; H. C HENDRICKSEN, B. Agr., specialist in farm management, San Juan; J. A. SALDANA, assistant in horticulture.

Virgin Islands Experiment Station

J. B. THOMPSON, B. S., agronomist in charge, St. Croix; C. E. WILSON, M. A., entomologist.

UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS

Washington, D. C. October, 1924

WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1922

By E. W. ALLEN, W. H. BEAL, and E. R. FLINT

CONTENTS

CONDITIONS OF THE YEAR

The fiscal year 1922 was a more favorable one for the agricultural experiment stations in the United States than any since the World War. Material relief from straitened financial conditions was provided, and the support of the system as a whole was the largest ever accorded it. In two-thirds of the States direct appropriations by the legislatures or allotments through the agricultural colleges increased the support for research, the total amount of this increase over the preceding year being nearly $1,300,000.

In individual cases this increase ranged from less than $1,000 to as much as $230,000 (in California), the latter, however, being due in part to change in the basis of estimating the amount used by the station out of general funds of the college. In over half the cases the amount of the additional funds ranged from $10,000 to $20,000. The wide distribution of these, covering so large a proportion of the stations, was quite as significant as the total amount, in the measure of relief afforded.

Another factor in the improved situation was a more liberal attitude on the part of the colleges, made possible by the relief which these had secured from the financial pressure they had themselves been under following the close of the war. The unfavorable position of the stations was beginning to make itself felt in the colleges and impressed upon the authorities the necessity for relief. Along with this was an increasing realization of the extent to which the ability of the colleges to keep their instruction fresh and to meet the changing demands of agriculture is directly dependent upon research.

The truth of this was brought home to a surprising degree by the few years of suspended growth during and following the war. Nowhere was it more felt than in the extension service, which had been rapidly built up and for which it was thought the accumulated fund of information would suffice for a considerable time. The application of existing facts and the stimulation of wider thinking and discussion set in motion by the extension work soon demonstrated the fallacy of this, for it very materially increased the call for assistance and presented new problems for study. It demanded, morever, a different kind of information, more far-reaching and enlightening, less empirical in many cases, in order that it might be better understood and more intelligently applied. The extension workers therefore became the most forceful advocates for continued investigation of a fundamental type and on a competent scale.

PROGRESS OF AGRICULTURAL RESEARCH

Farming is one kind of work which can not be carried on by fixed rule. It calls for adaptation of rules to conditions that are rarely twice the same in different years or localities. This has often made the laying down of specific advice a difficult matter for the man of science, and has sometimes led to his being regarded as vague or unpractical because of his caution in making broad practical generalizations. The recognition of this difficulty is one of the products of the extension method of imparting infomation. The carrying out of the latter soon leads to the necessity for deeper diagnosis and more intelligent prescription than the superficial facts enable.

The attempt to get at the whole truth, to disclose the real nature of a problem or difficulty, to combine reason with precept in prescribing for it, so as to furnish that understanding which lies back of the keen judgment and "common sense" of the practical man, requires a much more intimate and fundamental type of investigation than that which seeks merely superficial results or empirical rules. It calls for research of as abstract and exacting a type as that employed in any branch of science; and it requires those personal qualities of imagination and ingenuity which do not always accompany a wide scientific knowledge. It calls for patience with the methods of research, as the general public now increasingly realizes.

The reason lying back of a fact may be quite as important as the fact itself. The isolated fact may be well-nigh sterile or even dangerous unless it is understood, for if its limitations and its relationships are not known it may be misapplied or used with too much confidence.

Hence more and more the necessity is seen for getting away from the conventional methods which attempt to give direct answers to complex practical questions in the form in which they are commonly seen. The effort to go deeper imparts originality to the conception of the problem and the means of approaching it. Without analysis of many-sided questions and the devising of means for studying their essential parts step by step, the final result is likely to be inconclusive and unsatisfying, if not unreliable. The understanding of what is really involved in the intricate questions as met with in practice lies at the basis of successful investigation. When the essential features of such questions are dissociated and studied for themselves, special

investigations may be devised which give definite and often absolute results from which to develop both theory and practice. Until this is done results are largely comparative and relative, and subject to change with each variation in local or economic conditions.

Experiments find their justification not merely in themselves, but in the ends they serve. When they cease to meet the situation either by giving new evidence or suggestions or by supplying results sufficiently informing for the purpose, they need to be changed. The continued accumulation of data without being sure that they are meeting specific needs is inexpert and wasteful. The whole spirit of investigation is progress, which will develop one fact or point after another, or will open up the problem in a new light so that it can be attacked more effectively.

The type of station activity is therefore rapidly changing, a fact which the public sometimes views with concern lest the subject itself rather than its agricultural bearing may be the objective. Naturally this is to be guarded against, but it seldom occurs and is checked by the type of administration which keeps the mission and motive of the station clearly in the foreground.

It is inevitable that to be constructive and progressive, investigation should be much more technical than formerly; and the immediate results may appear of little importance to agriculture. This is the case, for example, with some of the fundamental studies in the relation between the plant and its environment, the soil in its relation to the life within it and the growth upon it, but it is through such studies that more intelligent practice based on an understanding of the facts must be founded.

The effect of this more intensive type of investigation is reflected in the requirements of the present day. What sufficed in the way of personnel, facilities, and equipment 10 years ago will no longer meet the situation. Success calls for investigators of extensive and severe training to give them vision and skill, and with demonstrated ability in the creative field of research. This fact is now recognized very generally as being in the interest of actual economy in the study of practical questions rooted in fundamental science; and the higher standards are being put into effect as far as financial and other considerations will permit.

Lack of funds has limited many of the stations in developing their work in accordance with these requirements, and salary precedent or adherence to a rigid scale in the college also acts as a bar. Means for attracting and holding competent investigators remains one of the great problems of the experiment stations. Steady progress in that direction, however, is evidenced by the increasing number of workers with advanced degrees, the type of work which they are doing, and less frequent change from one institution to another.

DIVERSITY OF WORK

Another factor which frequently enters into the situation is the fact that stations have "too many irons in the fire" for the resources at their disposal. In responding to the demands upon them they are attempting to cover too broad a field. This is not true of all, as some have continued to concentrate rather closely and not to enter upon

new undertakings until added funds were available; but quite often more lines are being attempted than can be carried on with vigor.

Instead of being regarded as a criticism of the stations this is to be taken as illustrating the ambition of their workers, and an earnest of the desire to serve. Every year sees a considerable increase in the number of projects. This number now aggregates something over 5,000, an average of about 100 to the station. This is manifestly too large a number for the average station to carry to advantage with its resources. As a result a considerable number are temporarily inactive or only prosecuted in an incidental way. They are usually the response to a request that the station do something on the subject.

Despite the large number of separate undertakings, the maximum attention is usually restricted to a relatively few projects. This concentration is commendable; and until support is received which enables a larger number to be given a similar degree of attention even greater restriction in the field covered might frequently be regarded as advisable. It costs something to carry along almost any project. A certain overhead is indispensable in keeping it alive, although inactive, so that it may be picked up when desired. This often involves land, stock, and facilities, which mean a continued expense sometimes not greatly less than when the work is on a more active basis. And when the work is revived it may need to be redirected.

Every consideration urges the concentration of effort within the means of the station to make that effort efficient and constructive. But the expanding demands for aid make such concentration difficult or impracticable, and this continues to enforce the need of more liberal provision for research.

DUPLICATION

From time to time there is indication of a feeling that considerable duplication is taking place in the work of the experiment stations. The inference is that there continues to be a considerable amount of unnecessary repetition by different stations.

There is admittedly considerable duplication in the sense that the same or similar subjects are under investigation at different stations, sometimes widely separated and sometimes in the same general region. Many of the leading subjects in the programs of the experiment stations are old ones. Varieties of fruits, vegetables, and other crops are being tested under new conditions, fertilizer experiments are being conducted on different soils under various cropping systems, feeding experiments are being made in the production of milk and meat, employing a wide range of farm-grown and commercial feeds. There are rotation series extending over long periods, farm management studies, culture and tillage trials with various crops, studies on the relation of stock and scion in fruit trees, experiments in the hogging off of crops, handling of flocks and herds, incubation of eggs, suppression of animal diseases, and the breeding of livestock. There are attempts to control common insects and plant diseases of long standing as well as newer enemies, there is progressive work on the handling of milk, the making of butter and cheese, and so on through the whole category of experiments.

However, these experiments are quite different from what they were a few years ago, both in purpose and plan, and they vary from one station to another. A certain amount of duplication is necessary in the practical range of experiments to meet local needs, and in more advanced lines repetition or continued study is essential for verification. To a great extent the status of work upon the familiar subjects of investigation reflects the state of knowledge which has developed with accumulated results.

Varieties are not being tested wholesale, as formerly, but largely in a restricted way and in connection with attempts at improvement in adaptation to a locality, or resistance to disease or some other quality. Wheat is being improved in Pennsylvania, Indiana, Kansas, Minnesota, California, Washington, and elsewhere. Oats are being bred for better strains in Maine, South Carolina, Ohio, New York, Michigan, Wisconsin, Iowa, Idaho, and other States. But it will hardly be maintained that this is duplication of an objectionable or unprofitable type. Recently a strain of oats produced in Maine showed qualities of advantage in Washington, and a variety of wheat originated in Kansas has spread over a wide region. Examples might be multiplied almost indefinitely. Crop improvement has been one of the large products of station work, and the result has fully justified the extensive work on which it has been based.

But what the casual observer evidently has in mind is duplication which is seemingly mere repetition, imitation without variation or any motive which contributes originality. Such an apparent going over of experimental fields already traversed is looked upon as unnecessary and unprofitable. And it would be if that proved to be the case when the circumstances were known. No one would attempt to justify it. But that the experiment stations are running along in a narrow groove, repeating one another's experiments without variation or to an extent which is unnecessary and unprofitable, is not evidenced by an intimate knowledge of their work the country over or a survey of their publications.

The history of experiment station work has taught caution in reaching practical conclusions and especially in applying them to a remote locality. Before transplanting such findings assurance will be desired both as to their applicability and practicability under the new environment. In this large country, representing such divergence of conditions, local applications must be based on experiments applicable to the section. Farmers are not content to be experimented upon themselves. They want general results or those derived elsewhere to be reduced to practice under their conditions.

Moreover, relatively little of the knowledge which now exists in agriculture is final or complete, any more than is that pertaining to electricity or the constitution of matter. Ideas regarding the nature of the atom have recently undergone very radical change on the basis of new investigation. So have those regarding the relative values of different foods and feeds, and the reason why some have superior qualities not accounted for by their composition or their action in mixed rations. Many workers are studying the vitamins as to their number, occurrence, special functions, and other qualities. What is already known about these substances which so long eluded scientists

is the product of many investigations and many minds. Progress will depend upon a continued multiplicity of effort.

Repetition in the making of experiments is essential to avoid error. Single trials or those covering a limited period rarely suffice. The results need to be verified, and to a certain extent they need to be tested at other stations. The Hatch Act anticipated this, and made it "the object and duty" of the stations "to conduct original researches or verify experiments." Naturally such verifications should be justified by the need, and this can not always be judged by the public. The seeming similarity of experiments is often explained on the ground that the subjects have not been exhausted and are being approached in different ways. The important thing is that the new investigation should begin where the previous work left off. If it repeats it in part it should be for the purpose of verifying a doubt and inaugurating something new. Again, it is frequently necessary to restudy, from time to time, problems which have been under investigation at an earlier date. As new facts are disclosed which throw different light on the subject it is often necessary to revive the work, and this may result in publications more or less similar to those of earlier days.

In the more advanced ranges of research there can be no danger of overduplication, provided each investigator embodies originality of ideas or methods in his attempt to get at the facts and their meaning. The more persons throwing their best constructive ability into the working out of a fundamental truth the better. One of them may succeed where others have failed to hit upon the right course or have overlooked some seemingly unimportant feature. This is the experience of all research in science where the attempt is to penetrate the unknown. The facts are elusive, and theories regarding them may be subject to revision.

In all investigation there inevitably will be experiments and inquiries which do not prove fruitful except in a negative sense. This is inherent in the nature of research. The investigator, like the searcher after gold, works over some ground which is unprofitable, but he does not do this purposely, and it is only as he continues to do so after he has discovered that ground to be unprofitable that he merits criticism.

To a considerable extent the suggestion of unnecessary duplication reflects a desire for more rapid advance, for a type of work which will make this possible. Sometimes the progress, from a practical standpoint, doubtless seems slow. Continuation is construed as duplication, ineffective because it does not reach more definite conclusions. It is doubtless true that some inquiries have proceeded about as far as they can until different means or a more analytic course is applied. More fundamental and far-reaching results will wait on more fundamental research. This, to a large extent, is the remedy for deferred conclusions, for seeming duplication.

RELATIONS WITH THE EXPERIMENT STATIONS

The Office of Experiment Stations maintained the usual close relations with the stations during the year, especially with those receiving the benefits of the Federal appropriations. In these relations and the supervision of the work under the Federal appropriations, there is no attempt at direction or control of research, or of

the lines it shall take; but the purpose is to insure that it is properly directed, is well considered at the outset, is not limited to unproductive repetition, and does not continue after it has ceased to make progress. The guiding purpose is to aid in securing favorable conditions for research, to stimulate investigators to their best efforts, to offer suggestion where it may be helpful, and to make the whole station enterprise as effective as possible, viewed as a national system which the Federal Government and the individual States are conducting in partnership.

The interest of the Federal Government is not confined to its contributions toward the maintenance of individual stations. It is not merely attempting to subsidize research in the States. It is endeavoring to assist in developing the most effective body of research possible for the benefit of a national industry, a body of knowledge whose application and value is rarely restricted by State boundaries. As an active partner the Government's interest extends to the point of developing favorable conditions to insure not only the proper use of the Federal funds but the employment of all available resources for research as effectively as possible. This cooperative view is expressed in the Hatch Act, whose purpose was "to aid" in the establishment and maintenance of experiment stations; and that this aid was not designed to be limited to the financial contributions is evidenced by provision for the relation of the department with respect to methods and results, the indication of important lines of inquiry, and the furnishing of "such advice and assistance as will best promote the purpose of this act."

In accordance with the usual procedure, each of the experiment stations was visited by a representative of the office during the year, its work and expenditures under the Federal funds examined in detail, and conferences held with the administrative head and the workers regarding the general progress and policy of the station. A revision of the classified list of projects carried on by all the stations was prepared and issued, to give timely information on the subjects under investigation at the various institutions.

The Adams Act is administered on the basis of definite projects, submitted by the stations and approved by the office in advance of the use of Federal funds upon them. A definite program of research is thus agreed upon at the beginning of each year, and if it is desired to inaugurate new projects during the year these are submitted and passed upon at any convenient time. The initiative in inaugurating research projects is left wholly to the individual stations, and a high degree of elasticity is preserved in arranging the annual program and using the funds.

In the examination of the projects submitted by the stations, effort is directed toward insuring that they are specific and limited in range, that the plan is adapted to the ends sought, and that the effort is upon a definite research plane. The requirements for carrying out the projects are taken into account, and suggestions are made for cooperation or for the addition of features which will place them on a competent basis. Attention is also given to the allotment of funds and the provision made for meeting the financial requirements of the projects. There has been some disposition to assign more projects to the Adams fund than could be properly supported

by it alone; and where other funds have not been available to adequately supplement the Federal funds the advisability of undertaking additional projects has been questioned.

As a rule the projects under this fund are supported in part from State funds, and in many cases the Adams fund contributes only a relatively small proportion toward the maintenance of the projects assigned to it. The stations could concentrate the Federal funds on a smaller number of undertakings and thus reduce the amount of supervision, but there has seemed no disposition to follow that course. The high grade of investigation for which the Adams fund stands has made many workers desirous of having projects under it and directors have welcomed the close supervision this entailed. Every effort is made to maintain the activities under this fund upon an energetic, progressive, and high research plane; and the influence which, in consequence, this fund has had on the development of research is far out of proportion to the amount involved. Similarly with the Hatch fund, care has been exercised that it should stand for substantial experimentation and investigation clearly distinguished from demonstration or random observation.

The growth of the stations and the steady development of their work furnishes a striking illustration of what may be accomplished through Federal leadership and stimulation without domination or attempt at control.

VISITATION OF THE STATIONS

A personal visit was made during the year to each of the continental stations receiving Federal funds by a representative of the Office of Experiment Stations. These visits as usual gave opportunity for a review of the work and expenditures of the year, conferences with members of the station staffs, suggestions regarding the work, and in general served to keep the office in personal and sympathetic touch with the organization, personnel, policy, and work of the stations. These visits were participated in by the chief (E. W. Allen), W. H. Evans, W. H. Beal, E. R. Flint, and J. I. Schulte. The office also continued to maintain close connection with the work and administration of the stations through extensive correspondence, review and approval of projects carried on under the Adams fund, examination of financial and other reports at the end of the year, review of publications relating to the work of the stations, and maintenance of up-to-date lists and records of station workers.

STATE LEGISLATION AFFECTING THE STATIONS

Comparatively few States passed any legislation that directly affected the stations during the year, as the following short summary shows:

In Indiana the Johnson Act, which was approved February 18, 1921, became effective July 1, 1922. This act gives the station two-fifths of a cent on each $100 of taxable property. It is estimated that this will yield permanently at least $200,000 per year.

In Michigan the State corporation tax law was declared constitutional by the State supreme court, adding largely to the funds of the

agricultural college for building and other purposes. At the beginning of the fiscal year the regulatory work previously done by the station, including the inspection of fertilizers, feeding stuffs, fungicides, and insecticides, as well as supervision of orchard, nursery, and apiary inspection, was transferred to the State Department of Agriculture.

In Nebraska a special session of the legislature, held in 1922, repealed the appropriation of $500,000 which had been made to the university to be used for building purposes. The supreme court of the State affirmed the law permitting the station to manufacture, buy, and sell antihog-cholera serum and virus.

In New Jersey acts were passed providing for investigations in the bee industry, with vegetables in northern New Jersey, and for studies on the root rot of peas.

In New York the legislature of 1922 authorized the New York State College of Agriculture and the New York State Experiment Station to initiate extensive investigations on the vegetable crops of Long Island. The college was authorized to purchase land, construct a laboratory and greenhouse, and to employ, besides labor, a special investigator in vegetable gardening. The experiment station was authorized to employ a special investigator in diseases of vegetable crops and one in insects attacking vegetables.

The Ohio station was placed under a new board of control, consisting of seven trustees of Ohio State University and the State director of agriculture.

In Texas an act was passed abolishing the separate governing board of the substations and transferring its functions to the board of directors of the Texas Agricultural and Mechanical College.

STATE APPROPRIATIONS

All of the experiment stations except one received some State support during 1922, although in several cases the amount was small or designed primarily for regulatory functions. Several stations received appropriations for the first time in many years.

A large number of the stations are now receiving liberal State appropriations. During the year covered by this report the stations in California, Illinois, Minnesota, and Ohio received over $300,000 each from the State; those in Indiana, Iowa, Texas, and Wisconsin between $200,000 and $300,000 each; and 11 other stations had between $100,000 and $200,000 each from this source. Six stations each received $10,000 or less. It should be noted, however, that the State appropriations do not always represent amounts devoted strictly to investigation, as in many cases they include funds appropriated specifically for work of a regulatory or similar nature. They include in many cases also money for the erection of buildings, the purchase of land, the support of branch stations, overhead expenses, and the like.

There were notable increases in State appropriations for the experiment stations during the year, few stations reporting no increase or a decrease. The total net increase was $1,278,634. The increases and decreases in State appropriations during the year as compared with the preceding year are given in the following table:

TABLE 1.—*Increases, decreases, and total amounts of State appropriations for the experiment stations, 1922*

Station	Increase	Decrease	Total
Alabama			$34,500
Arizona	$17,250		66,532
Arkansas	13,871		56,946
California	232,622		380,000
Colorado	34,357		109,686
Connecticut State	22,922		61,122
Connecticut Storrs		$10,322	17,500
Delaware	5,000		15,000
Florida	50,000		55,000
Georgia	11,715		11,766
Idaho		11,225	10,033
Illinois	170,294		310,294
Indiana	65,750		215,983
Iowa	109,500		250,000
Kansas	15,000		97,000
Kentucky			50,000
Louisiana			50,000
Maine	16,146		31,146
Maryland		4,404	49,624
Massachusetts	15,953		99,153
Michigan		107,013	90,000
Minnesota	87,943		306,943
Mississippi	7,548		102,377
Missouri	6,885		42,087
Montana	55,073		134,469
Nebraska	20,018		71,742
Nevada	1,737		1,878
New Hampshire	5,000		5,000
New Jersey	23,794		142,957
New Mexico			7,500
New York Cornell		9,155	183,474
New York State	12,525		198,355
North Carolina	59,187		162,737
North Dakota	48,226		151,334
Ohio	45,276		310,641
Oklahoma	500		10,500
Oregon	14,794		107,544
Pennsylvania	36,436		36,436
Rhode Island	7,359		9,052
South Carolina	7,987		57,987
South Dakota		40	14,420
Tennessee	1,391		33,295
Texas		18,984	201,535
Utah		3,345	50,124
Vermont			
Virginia	6,948		45,298
Washington	16,914		104,675
West Virginia	15,213		120,000
Wisconsin	5,000		215,000
Wyoming	12,500		12,500
Total	1,278,634	164,488	4,901,145

ADDITIONS TO BUILDINGS AND EQUIPMENT

At the Arizona station a gin for small samples of cotton and a 10-saw gin for larger amounts were purchased. A screened garden for cotton experiments was constructed on the campus. An appropriation of $12,500 was made for the construction of a new poultry plant, and five blocks of land were secured, costing $5,000. Twelve other blocks near the university were also secured. At the Sulphur Springs Valley Dry Farm four corrals were built. At the Prescott Dry Farm the barn, two feed corrals, and a modern farm dwelling costing about $4,800 were completed. A small two-room frame house was also built at the Yuma Mesa Farm, and 4½ acres were added to the farm at a cost of $2,250.

At the Arkansas station a new greenhouse costing $2,800 was completed and occupied. A hog house costing $2,600, a beef cattle shed costing $1,000, and a seed and fertilizer house costing $1,600 were

completed. Four laborers' cottages, costing $1,000 each, were built on the recently acquired farm. The horticultural department added about $1,000 worth of improvements.

At the California station the new dairy industry building, costing with equipment approximately $225,000, and the new building for pomology, viticulture, and botany, costing $120,000, provided for by the last legislature for the Branch College of Agriculture at Davis, neared completion. It was expected that this would release the old horticultural building for work in chemistry and zoology and the former creamery building for soil technology and irrigation. Further improvements at Davis included an agronomy warehouse, equipped with seed-cleaning machinery; a modern fruit-packing and cool-storage house; a new wool laboratory equipped with a gas-heated drier; a modern electrically operated conditioning oven; and an irrigation field laboratory equipped to test and demonstrate practically all of the standard irrigation appliances used in practice. A group of ranch buildings, including dining hall, sleeping quarters, and implement shed, was also added; a new water tank was erected and 370 acres provided with underground irrigation pipes. The Citrus Experiment Station at Riverside was improved by fencing, installation of a separate domestic water system, and extension and improvement of the irrigation system on the experimental plats. An appropriation of $129,000 was made to complete the purchase of land for the southern branch of the College of Agriculture. On the Hunt tract, recently acquired by the university, a pumping plant was installed. At Berkeley a laboratory for the semicommercial production of canned fruits and vegetables, fruit sirups, jellies, candied fruits, vinegar, vegetable oils, and other similar food products was fitted up with canning and preserving equipment to the value of $5,000.

At the Florida station a brick laboratory to cost $12,000 was begun at the citrus branch station at Lake Alfred, also a residence for the superintendent to cost $3,739. At the tobacco station at Quincy, 23 acres of land costing $3,500 was purchased and a laboratory building to cost about $13,021 partly completed.

At the Georgia station provision was made for rebuilding one of the greenhouses to be used by the department of botany for plant-disease work. A small summerhouse was constructed for farmers' clubs and picnic parties.

At the Illinois station the legislature appropriated $500,000 for the first unit of an agricultural group of buildings and construction was begun during the year. A horticultural field laboratory costing $260,000 was completed.

At the Indiana station an additional farm of 120 acres near the university was bought for experiments with fruit varieties, orchard management, and the production of truck crops, and the purchase of a suitable tract for experimental work with livestock was authorized. An incubator cellar and a hospital were built on the poultry farm. The 40-foot extension of the dairy barn to accommodate 20 additional cows for experimental purposes was completed. The construction of a new home economics building was commenced during the year.

At the Iowa station a new hog barn, a judging pavilion costing $20,000, a number of poultry buildings, including rearing and laying houses, and a new building to house educational and research work

in agricultural engineering, costing $75,000, were completed and occupied. Twenty thousand dollars became available for a sheep barn and pavilion. A fertilizer house was built on the agronomy farm for the soils section at a cost of about $2,500, a frame building for feed storage was erected on the animal husbandry farm, and a cold-storage laboratory for pomology was installed with respiration equipment. A new 178-acre farm purchased for the animal husbandry department was fenced and graded, and the forestry nursery was increased in acreage.

At the Kansas station construction was begun on an addition to the agricultural building to cost $275,000, which will house the departments of agricultural economics, dairy husbandry, and poultry husbandry; and construction of a $25,000 annex to the east wing of the agricultural building for use as a meat laboratory was in progress. Two hundred and fifty acres of native pasture land was purchased for the use of the animal husbandry department, and a weighing outfit was installed at a cost of $1,000. The greenhouse was repaired. A machine shed was built at the Fort Hays station at a cost of about $4,000.

At the Louisiana station construction of a new hog barn and of a cattle barn at the new agricultural college site was in progress. Several pieces of scientific apparatus were added to the equipment.

A new chemical laboratory, to cost $300,000 and to house some station activities, was commenced at the Massachusetts Agricultural College. The Brooks farm of 60 acres was purchased for $15,000 and will be used for tobacco and onion studies. The station has come into possession of 50 acres at Waltham for market garden work.

At the Minnesota station the construction of a new dairy building to cost about $250,000 was authorized.

At the Missouri station a new agricultural building costing $200,000 was under construction. This building will house the offices of the dean and director, and the agricultural editor, the mailing room, agricultural library, seminar room, and the departments of soils, rural life, and poultry. The construction of a new beef cattle barn for 100 head of cattle, with winter feed, to cost $25,000, was started. The third floor of the horticultural building was remodeled at a cost of $4,000, and the basement of the biology building was finished at a cost of $10,000, to be occupied largely by the departments of zoology and botany. Material additions were made to the poultry plant. Various other buildings were being constructed at the university, which will have a bearing on the station work.

At the Montana station the old barracks building was remodeled for agricultural engineering at a cost of $10,000. New buildings under construction at the college included a biology building costing $175,000, an engineering building costing $250,000, shops costing $100,000, a gymnasium costing $225,000, and a central heating plant to cost $150,000, and $250,000 was appropriated for furnishing and equipping the new buidlings.

At the Nebraska station a new cattle barn costing $30,000 was provided for, the dairy department to take over the old barn. At the Valentine substation, an open shed, a single-unit poultry house, and a new corral fence were constructed.

At the Nevada station 3,500 feet of dog-proof fencing was put up and an open shelter for lambing for the station flock was built.

At the New Jersey stations a poultry husbandry building costing $85,000 was practically completed during the year. A new horticultural building was completed in July, 1921. The 1922 legislature appropriated $150,000 for a new dairy and animal husbandry building and $20,000 for equipment of the poultry building. Other buildings added included a new piggery, a concrete garage, and a storage building.

At the New Mexico station the old greenhouse was rebuilt and a smaller poultry house was added to the poultry farm.

At the New York Cornell station a new dairy building was in process of erection, nearly $400,000 being available for it in addition to over $200,000 for equipment. Some smaller new structures were added, including a cold-storage plant for pomology and an insectary with a glass laboratory, and a field was secured for plant breeding.

The New York State station equipped a complete constant low-temperature room for ice-cream investigations.

At the North Carolina station a new building for the State department of agriculture, to cost about $375,000 with equipment, was being constructed at Raleigh, and will be used in part for station work. A new poultry plant, dairy equipment, and three cottages for labor were added to the Mountain Branch station at Swannanoa. A new sweet-potato storage house with a pecan-curing room was built at the Edgecomb Branch station at Rocky Mount. At the Blackland Branch station at Wenona a new swine plant and a cottage for the foreman were built.

At the North Dakota Agricultural College a new agricultural building was in process of erection, which is primarily for college use but will release other space for station use. New barns were erected at the Hettinger and Langdon substations.

A new dairy barn at the Oklahoma station was occupied.

At the Oregon station the completion of a new building for the school of commerce made it possible to secure additions to station laboratories for bacteriology, horticulture, entomology, farm crops, and soils. Considerable equipment was added to the central and branch stations, including a new cottage, remodeling of the stock barn, and the extension of city water and electric lines at the Union branch station.

A new beef-cattle barn was being erected at the Pennsylvania station. Complete gas-analysis apparatus was installed at the Institute of Animal Nutrition.

At the Rhode Island station the new agricultural and administration building was dedicated during the year.

In South Carolina a new silo for beef-cattle experiments was built at the college and also one at the coast station.

At the South Dakota station 15 acres of additional land was provided for the horticultural department.

At the Tennessee station a battery of 12 tanks was added to the lysimeter equipment, making this probably the most complete in the country.

The Texas station installed a complete wool-scouring plant.

At the Utah station a 10-acre tract of land was purchased for pasture experiments. The water measurement and pumping laboratory was completed. An electrically heated Kjeldahl digestion and dis-

tillation outfit of six units was installed in the soil-survey laboratory. New apparatus was added to the station.

At the Virginia station a fully equipped barn partly paid for by the college was provided for experimental work with dairy cows. A battery of lysimeters was completed. A barn and a granary were built at the Bowling Green station.

At the Washington station a beef-cattle barn and a sheep barn were completed. Two cement silos were constructed in connection with the cattle barn and a wooden silo in connection with the sheep barn. These are for the college of agriculture, but they will help in the investigational work. The old cattle barn was remodeled for the dairy herd. At the Prosser branch station a silo, corrals, and feeding lots for sheep and cattle were constructed.

At the West Virginia station a new dairy barn estimated to cost about $30,000 was in process of erection.

At the Wisconsin station a beef cattle barn costing about $16,000 was erected during the year.

At the Wyoming station about $4,000 worth of additional livestock was purchased for the farm.

CHANGES IN PERSONNEL

During the fiscal year there were six changes in directorship of the stations. At the Arizona station J. J. Thornber succeeded D. W. Working. W. R. Dodson returned to the Louisiana stations as director, succeeding W. H. Dalrymple. R. W. Thatcher succeeded W. H. Jordan as director of the New York State station. C. G. Williams, who had been acting director of the Ohio station since the retirement of Director C. E. Thorne, was made director in August, 1921. F. S. Harris resigned as director of the Utah station and was succeeded by William Peterson. H. G. Knight was elected director of the West Virginia station.

At the Alabama station E. F. Cauthen resigned as agriculturist and F. W. Parker was appointed soil chemist.

The most important changes at the Arkansas station included the appointment of S. J. Schilling as associate veterinarian, A. D. McNair as specialist in farm management, F. A. Wirt as head of the department of farm machinery. W. J. Baerg returned from leave of absence as head of the entomology department.

H. J. Webber returned to the California station in charge of work in citriculture, and C. B. Hutchison was made professor of plant breeding and director of the branch of the College of Agriculture at Davis. Other appointments included A. J. Winkler, associate in viticulture, and J. P. Conrad, associate in agronomy.

At the Colorado station I. G. Kinghorn was appointed editor.

W. L. Slate, jr., was appointed vice director of both of the Connecticut stations. G. H. Chapman was placed in charge of the tobacco work at Windsor.

At the Florida station W. E. Stokes was appointed in charge of forage crop investigations, and W. B. Tisdale was put in charge of the Quincy tobacco station.

At the Georgia station J. A. McClintock, plant pathologist, resigned to become associate plant pathologist at the Tennessee station.

H. P. Davis, head of the dairy department, resigned to go to the Nebraska station and was succeeded by F. W. Atkeson. C. Wakeland was appointed field entomologist to succeed R. H. Smith.

A number of changes were reported from the Illinois station. Those involving the more important positions included the appointment of A. H. Ruehe as head of the dairy department, H. P. Rusk as head of the animal husbandry department, and L. E. Card as head of the poultry husbandry department. C. F. Hottes was appointed consulting plant physiologist in the agronomy department; A. L. Whiting, chief in soil bacteriology, resigned. G. E. Fager was appointed associate in plant breeding. H. S. Grindley, chief in animal nutrition, returned from sabbatical leave, and J. A. Detlefsen was granted leave of absence. A number of assistants were appointed during the year.

At the Iowa station W. H. Stevenson, chief in agronomy, was absent during the year as American delegate to the International Institute of Agriculture at Rome. H. D. Hughes, chief in farm crops, and J. M. Evvard, chief in swine and beef-cattle investigations, were on leave of absence. A. C. McCandlish, chief of the dairy section, resigned, and F. F. Sherwood was appointed assistant chief of this section. C. J. Drake was appointed chief of the entomology department.

The more important changes at the Kansas station included the appointments of N. E. Olson as associate in dairy husbandry, succeeding O. W. Hunter, and L. C. Aicher, superintendent of the Fort Hays branch station, succeeding H. L. Kent. In addition, there were a number of appointments and resignations of assistants in various departments.

At the Louisiana stations W. L. Owen was appointed bacteriologist at the sugar station. G. D. Cain, in charge of the North Louisiana station at Calhoun, resigned and was succeeded by Sidney Stewart. B. Szymoniak was appointed in charge of the fruit and truck station at Hammond.

At the Maryland station DeVoe Meade was transferred from the college to part-time station work in animal husbandry.

The changes at the Massachusetts station included the resignation of G. H. Chapman as research plant physiologist, his place being filled by transferring P. J. Anderson from the instruction staff. A. P. French was appointed investigator in pomology and H. D. Goodale resigned as research professor in poultry husbandry.

At the Michigan station E. C. Foreman succeeded C. H. Burgess as head of the poultry department, and O. E. Reed was appointed head of the dairy department. P. S. Lucas was appointed research associate in dairy manufacture, and C. F. Huffman research assistant.

In addition to the change of directorship at the Minnesota station, mentioned above, J. H. Beaumont succeeded M. J. Dorsey in charge of fruit breeding, and P. F. Sharp, associate in milling and baking, resigned.

At the Mississippi station H. B. Brown resigned as plant breeder and was succeeded by J. F. O'Kelley.

Although a number of changes were reported from the Missouri station, most of these were among the assistants. The most important change was the appointment of E. L. Morgan in rural sociology.

The principal changes at the Montana station included the appointment of Clyde McKee head of the department of agronomy, and of F. M. Harrington head of the department of horticulture. There were numerous changes among the assistants.

Changes at the Nebraska station included the appointment of M. J. Blish as head of the chemistry department, and of H. P. Davis as head of the dairy department. F. D. Keim, of the agronomy department, was transferred to the college. A number of changes occurred among the assistants.

At the New Jersey stations W. C. Thompson was appointed head of the poultry department and R. R. Hannas superintendent of egg-laying contests. W. Rudolfs was appointed biochemist.

New appointments at the New Mexico station included J. H. Bardsley in the poultry department, succeeding F. E. Uhl, and C. W. Botkins as chemist, holding also the office of State chemist. The resignations included Luther Foster in the animal husbandry department and L. S. Brown, nutrition chemist, the latter succeeded by H. W. Titus.

At the New York State station G. A. Smith resigned from the dairy department and was succeeded by A. C. Dahlberg. In addition to these there were various changes in the staff of assistants.

At the Ohio station E. Secrest, of the forestry department, was appointed associate director. G. Bohstedt was appointed chief of the animal husbandry department and D. C. Kennard associate chief. J. H. Gourley was appointed chief of the horticultural department. W. K. Greenbank suceeded C. M. Baker as editor. C. W. Montgomery, chief in farm management, was made also superintendent of county farms, succeding J. P. Markley in the latter capacity. There were a number of appointments and resignations among the assistants.

The only important change at the Oregon station was the resignation of James Dryden, head of the poultry department, who had been on leave of absence. H. G. Miller, associate chemist, was absent on leave.

The Pennsylvania station lost two important members of its staff by death during the year—William Frear, head of the department of agricultural chemistry and vice director, and H. P. Armsby, director of the Institute of Animal Nutrition. Doctor Frear was succeeded by R. A. Dutcher. Other changes on the staff involved assistants only.

At the Rhode Island station a department of marketing and economics was established and H. B. Hall was appointed in charge.

At the Tennessee station G. M. Bentley was transferred entirely to instructional work, being succeeded as station entomologist by S. Marcovitch. J. A. McClintock, of the Georgia station, was appointed associate plant pathologist.

Changes at the Texas station included the appointment of J. L. Lush as animal geneticist. H. B. Parks succeeded L. R. Watson as apiculturist. The resignations included E. W. Geyer as agronomist and A. B. Cox, chief of the division of farm and ranch economics.

At the Utah station, in addition to the change in the directorship, I. M. Hawley was appointed entomologist. T. H. Abell was placed

in charge of the horticultural department on the resignation of M. C. Merrill. G. Wilster was appointed associate in dairy husbandry. Miss Blanche Cooper resigned as associate in human nutrition.

At the Washington station E. V. Ellington succeeded E. G. Woodward as head of the dairy department.

In addition to the change in the directorship of the West Virginia station, already noted, M. J. Dorsey succeeded J. H. Gourley as head of the horticultural department. B. H. Hite, head of the chemical department, died in October, 1921.

PROJECTS IN 1922

The total number of projects carried on by the State experiment stations in 1922 was 5,156, an average of about 103 per station, a slight increase over the previous year. Of these, 490 projects, or nearly 10 per station, were conducted under the Adams fund, a slight decrease for the year. Of the total number of projects, 56 were purely administrative, control, or regulatory. Subtracting these leaves 5,100 devoted to research and experimentation, to which may be added 140 projects carried on by the experiment stations in Alaska, Guam, Hawaii, Porto Rico, and the Virgin Islands, giving a total of 5,240 research projects.

The list shows an increase of 385 in the total number of projects during the year. This increase is probably not due wholly to an extension of the work, but partly to splitting up of more generalized projects into those of a more specific nature and to the more general use of the project system of recording the work.

An analysis of the projects shows little relative change as compared with last year's record. Field crops leads with a total of 1,611 projects, corn being the subject of 183, followed by potatoes with 153 and wheat with 143. The second largest group in the list is horticulture with 904 projects, under which the leaders are apples with 118 projects, fruits (general) with 61, and vegetables with 58. Plant pathology comes third in the list with a total of 452 subjects, the largest subheads being potato diseases with 51, cereal diseases with 34, and apple diseases with 32 projects. Economic entomology follows with a total of 412 projects, the larger subdivisions of which were bees 45, insecticides 39, and miscellaneous 20. The next largest division is soils with 310 projects, including soil fertility 46, soil flora 38, and soil types 29.

The subject of veterinary medicine includes 194 projects, fertilizers 193, rural economics 186, and rural engineering 162. The number of projects on swine is 180, dairy cattle 176, poultry 170, beef cattle 88, and sheep 74, while there are 111 on feeding stuffs and animal nutrition and 105 on genetics.

The largest increases over the previous year were in horticulture with 96 and fertilizers with 52 more projects. There was a slight falling off in the number of projects under foods and human nutrition, feeding stuffs and animal nutrition, chemistry, and bacteriology.

105313—24——2

SOME RESULTS OF STATION WORK

By E. R. Flint

The following is a résumé of some of the outstanding results of station work during the year, the purpose of which is to give a general view of the progress made.

SOILS AND FERTILIZERS

Rare constituents of soils.—The universal distribution of manganese in soils and plants is indicated by investigations reported by the Kentucky station. Apparently the manganese performs an important function in plant nutrition and is essential in small amounts to the growth of the higher plants. Manganese was found to be toxic to plants in acid soils, but the toxicity was corrected by liming. Colorado soils contain considerable amounts of barium, strontium, lithium, and other comparatively rare or unusual elements. The Colorado station found that when grown on such soils, alfalfa was relatively rich in barium and strontium, but poor in lithium; tobacco contained barium and lithium, but little strontium; and potatoes contained strontium and lithium, but no barium; whereas corn contained all three, as well as considerable titanium.

Soil colloids—The Missouri station reported a method of separating the colloids by a high-power centrifuge. Analysis of the material so obtained showed the main constituents to be SiO_2 46 per cent, Al_2O_3 24 per cent, Fe_2O_3 7 per cent, and water 20 per cent. Further studies showed that the material is not made up of appreciable amounts of the free oxids, but is largely a highly hydrated complex aluminosilicate, which may be considered the end product of the weathering of certain soil materials in humid, temperate regions. The material was found to flocculate more readily with acid sodium phosphate than with lime. In experiments at the Utah station with a series of soils ranging from sands to light clays, comparable vapor pressure moisture curves were found to maintain nearly constant ratios of hygroscopic water over a wide range of vapor pressure, and the results are believed to confirm the theory of the "colloid-coated particles" of English investigators. It was found that soluble salts may flocculate at one concentration and deflocculate at another.

Soil moisture.—The Nebraska station found moisture penetration to be much slower in a thoroughly dry soil than in a moist one. Capillary rise and consequent loss of moisture from the surface of dry-land soils, where the water table lay at a considerable depth, was very slight. Lateral or downward movement of moisture in soil was very slight after the first or second day following rains. The chief agency in the exhaustion of soil moisture is the crop growing upon it. In tillage tests it was found that in soils where the available moisture was the limiting factor, summer tillage and early fall plowing served best to store and preserve the soil moisture; but summer tillage did not return a profit with corn or with grain crops except in those years when yields from ordinary practices were considerably depressed by lack of moisture.

Experiments at the Minnesota station showed that rolling a sandy soil or the addition of crop residues or of peat decreased evaporation

and increased water retention in the soil. Addition of lime did not increase the water-holding capacity to any appreciable extent.

The use of water by wheat and other small grains on dry land was found by the North Dakota station to amount to about 0.16 inch per day from stooling to maturity.

The Washington station found that under drought conditions an abundant supply of nitrate nitrogen, with a consequent heavy yield of straw, tended to reduce the yield of grain. It therefore appears that during a season of drought it is more important to center tillage operations on saving a maximum supply of soil moisture than on developing nitrates. Tillage experiments showed that the earliest possible spring preparation of the summer fallow led to a greater accumulation of nitrates than later preparation. It also showed that very early preparation did not conserve appreciably more moisture than a later one, if the latter preceded the active growth of volunteer grains and weeds.

Soil erosion.—In experiments at the Missouri station on a soil having approximately a 4 per cent slope, the greatest erosion and accompanying loss of nitrogen occurred in shallow plowed continuously cultivated soil, the least in soil under continuous sod. Intermediate rates of erosion in descending order were observed in case of continuous corn culture, continuous wheat culture, and a rotation of corn, wheat, and clover. The estimated rate of erosion in case of continuous sod was 7 inches in 2,336 years with an insignificant loss of nitrogen. The same soil plowed 4 inches deep and cultivated eroded at the rate of 7 inches in 25 years.

Soil acidity.—Studies at the Indiana station indicated that the beneficial action of acid phosphate in preventing injury to plants by soluble aluminum salts in acid soils was not altogether due to prevention of absorption of the aluminum salts by the plant, but partly to some action of the phosphorus on the aluminum in the plant.

The Michigan station found soil components, separately or collectively, to be amphoteric in nature, the degree of acidity in soils being proportional to the ratio between the active bases and acids, and not to the excess quantity of active acids. The degree of acidity of soils did not correlate with the quantity of base required for neutralization (lime requirement), the latter depending upon the excess of active acids over active bases. The reaction of soils appears to depend upon the quantity relationship between hydrogen ions and hydroxyl ions in the soil solution, a relationship which can be determined by means of an indicator dye (bromthymol blue) and the use of pure water to obtain a soil extract.

The New Jersey stations found that when calcium nitrate was used in connection with ammonium sulphate, the nitrate ion was absorbed, leaving the lime to counteract the acidity; with ammonium sulphate alone, the ammonium ion was absorbed, the remaining sulphuric acid thus increasing the acidity. When nitrogen was present as ammonium and nitrate in the same solution, the plant took up first the ammonium nitrogen and then the nitrate nitrogen.

Studies at the Oregon station showed that in a soil whose crop-producing power had been depressed by the application of lime, the pH value was 7 or greater. The growth of plants appeared to be more closely associated with the ionization than with the titratable acidity.

The Rhode Island station found that Thomas slag, acid phosphate, and ground bone were especially active in reducing soil acidity. Acid phosphate did not increase acidity as is commonly believed. All potash salts slightly reduced acidity, kainit being most active in this respect. Leguminous cover crops tended to increase the soil acidity appreciably, but nonlegumes slightly decreased it. If the pH value is kept down to 4.5 to 5, weeds may be kept out of lawns.

At the Washington station an examination of a large number of acid soils from regions where the precipitation varied from 7.5 to 21.5 inches showed that the percentage of nitrogen and carbon increased with the precipitation; but the ratio of 1:12 remained practically constant for all soils, this being about the same as for soils from humid regions.

Soil alkalinity.—Experiments at the Arizona station showed that practically all chemicals that react to sodium carbonate reduced the toxicity of black alkali. Partial neutralization was nearly as effective as complete neutralization. Neutralization seemed to give better results than elimination by leaching alone. By the combined action of gypsum and manure the productivity of black alkali soil has been sucessfully brought up to that of ordinarily fertile soils. Tepary beans did not germinate with 0.25 per cent of black alkali. With 0.2 per cent they germinated but died. The limit was found to be 0.15 per cent of sodium carbonate. Cotton plants also died with 0.25 per cent. The limit was 0.2 per cent for most crops tested, especially wheat and barley, although the former is somewhat more resistant than the latter. With Mexican June corn, 0.1 per cent was the limit. Plants are more resistant on heavier soils than on sand.

In experiments at the Oregon station an application of 500 pounds of sulphur resulted in the removal of 65 per cent of alkali in the drainage, and applications of gypsum and lime removed 60 per cent. A smaller quantity was removed by aluminum sulphate. The Utah station found, in general, that the addition of more than very small amounts of other soluble salts increased the toxicity of sodium carbonate in an alkali soil. Applications of manure, gypsum, and small amounts of nitrates produced some improvement.

Lime and liming.—The Virginia station obtained good results in crop production with a lime-magnesia ratio of 1:1; but when the ratio became 1:2 yields were depressed. The Iowa station found a close relation between the amount of carbon dioxid given off by the soil and its lime requirements. The Delaware station found all forms of lime to be equally valuable in decomposing green manures as measured by the amount of carbon dioxid given off. Magnesium limestone, as well as ordinary limestone in a fine state of subdivision, was especially active when first applied, but eventually the amount of carbon dioxid given off was about the same for all forms of lime.

The Iowa station found gypsum applied to various soils of the State to be of little or no economic value in any case. The Tennessee station found that the initial toxicity to seedlings, due to noncarbonate residuals from precipitated magnesium carbonate after its disintegration and fixation in the soil, was followed by a period during which a favorable response was obtained. The initial results dependent upon the lime-magnesia ratio were at variance with those secured later.

The residual effect of one crop on another is, according to the Rhode Island station, largely a question of soil reaction and can be largely corrected by liming.

Soil bacteriology.—In experiments at the Colorado station fixation of nitrogen by Azotobacter took place within narrow limits of soil reaction and stopped when the pH value reached 5.7, the optimum being 7.5. Plowing under of millet depressed nitrogen fixation in the soil, as did application of sulphur. Accumulation of nitrate nitrogen increased rapidly as long as the soil was alkaline. Sulphur and ammonium sulphate depressed nitrification. Of 481 soils examined at the Kansas station only 199 contained Azotobacter. The critical point for nitrogen fixation was found to be pH 6. Very few soils more acid than this contained Azotobacter, and very few less acid than this failed to show the presence of the organism.

At the Idaho station alkali salts were found to stimulate bacterial activity in some soils, while in others they were distinctly toxic. Sodium chlorid and sulphate decreased ammonification, but sodium carbonate increased slightly both ammonification and nitrification in some cases.

In studies at the Utah station various salts, including carbonates, chlorids, sulphates, and nitrates of sodium, magnesium, calcium, and iron, applied to soils in small quantities, increased the bacterial activity, as manifested by increased production of ammonia, nitrates, soluble phosphorus, and nitrogen fixation. The nitrifying organisms were more sensitive to alkali than the ammonifying, which tolerate large quantities of alkali. The salts apparently form compounds with the protein of the organisms other than those normally occurring in living protoplasm, thus making them incapable of functioning normally. Osmotic changes also appear to play a part in bacterial activity. Some alkali soils appear to be unproductive as a result of the action of the salts upon the flora and only indirectly through toxicity to the higher plants. The optimum moisture content of the soil for maximum bacterial activity, stated in water-holding capacity of the soil, was found to be 60 per cent for ammonification and 50 to 60 per cent for nitrification, this holding true in all kinds of soils. These are also near the optimum content for the higher plants.

At the New Jersey stations organic matter stimulated the development of all groups of soil microorganisms studied. Lime increased the number of bacteria and to a still greater extent the Actinomycetes, but caused a relative decrease in fungi. The continued use of ammonium sulphate without lime resulted in a decrease of bacteria and a much greater decrease in Actinomycetes, with a relative increase in the number of fungi. A reaction equivalent to pH 5 to 5.2 was found to prevent the growth of Actinomycetes in liquid cultures, and pH 4.8 to 5.2 was the limiting point for their growth in soils. When organic matter in the form of manure or green manure was applied to the soil, the number of Actinomycetes increased rapidly. The use of lime produced very favorable conditions for the development of Actinomycetes.

In experiments at the Washington station the plowing in of straw just before seeding wheat resulted in a decrease in available nitrogen in the soil and in reduced yields of an inferior quality. The greatest reduction in nitrates and yield resulted where the moisture

content of the soils was lowest. There was no reduction when the moisture content was kept at the optimum for nitrification. In tests at the Idaho station of the effect of various forest materials on ammonia and nitrite accumulation in the soil, it was found that the greatest reducing effect occurred with cedar sawdust and needles, ranging from 5 to 60 per cent. Nitrogen fixation was reduced by some of the tree products tested and practically eliminated by others.

The Missouri station found that when the surface soil was covered an inch deep with straw, nitrification was inhibited in the first 7 inches, and that cultivation lessened the amount of nitrates in the first 7 inches in the same depth of soil. The New York Cornell station found that growing corn stimulated nitrification in the early stages and retarded it later.

Soil inoculation.—At the Missouri station samples of soil in which soy beans and red clover had grown with abundant nodules were subjected to various treatments for four years, including exposure out of doors, but with protection from contamination, and drying in the sunlight and in the dark. After the treatment all of the samples still had enough viable bacteria to produce good inoculation. The test indicated that soil once inoculated for soy beans and red clover need not be reinoculated when these crops are grown in a four-year rotation. Tests at the Wisconsin station of cultures from nodules of alfalfa, soy beans, and clover showed that these lost their power to inoculate their host plants in 75 days when the soil was distinctly acid, but retained their vitality much longer in neutral soils.

Sulphur.—The Illinois station observed that the amount of sulphur added in rainfall ranges from almost negligible quantities to considerably more than total removals in crops and drainage water. The variation in soil sulphur runs, in general, parallel to those in organic carbon.

At the New Jersey stations two sulphur oxidizing organisms were isolated in pure culture, one of which is new. One rapidly oxidizes elementary sulphur and to some extent thiosulphates and sulphids, with quantitative formation of sulphuric acid. The second organism oxidizes elementary sulphur to a limited extent only, and acts mainly on thiosulphates and sulphids. The acid formed renders rock phosphate soluble, the process being most active when the reaction of the medium is between pH 2.6 and 3.2. The addition of sulphur to alkali soils results in reducing the alkalinity.

The Oregon station found that soils from different parts of the State oxidized sulphur as rapidly as would be required for maximum crop production. There was no apparent relation between the total sulphur content and the sulphur-oxidizing power of the soil. The application of sulphur brought about an increase in the sulphur-oxidizing power by making the soil a more favorable medium for the growth of sulphur-oxidizing organisms. Temperature and moisture of the soil were found to be important factors in the rate of oxidation, although oxidation was active even in an air-dry soil.

The Tennessee station found that all forms of calcium and magnesium materials tend to accelerate the outgo of sulphur from surface soils, even in the case of light additions. Increasing the amounts of native limestone and magnesite produced no consistent variation from the effects induced by the lighter treatments, but increasing the

amount of dolomite applied caused a marked increase of sulphate produced. This was also true of magnesium oxid, but not of calcium oxid. The power of the subsoil to stop the outgo of both basic and radical ions was overcome by the more soluble magnesium salts. Magnesium, especially in large quantities, was found to accelerate the generation and leaching of sulphate sulphur.

The Washington station found that applications of elemental sulphur at the rate of 160 to 500 pounds per acre caused an accumulation of soil nitrates, whereas 1,000 pounds caused a decrease. Nitrate accumulation was decreased by the use of sulphur on manured soils. The rate of oxidation of the sulphur was affected but little by the addition of manure.

Nitrogen.—The Montana station found that nitrogen was made available slowly in undisturbed virgin soils, but more rapidly under summer fallowing, cultivation, or manuring. An intermediate rate was found in soils cropped every year to small grains. The rate was increased by adding lime to soils showing an acid reaction.

The Pennsylvania station, after 40 years of continuous cropping, found the percentage losses of nitrogen applied to be as follows: With manure 63, nitrate of soda 58, dried blood 59, and sulphate of ammonia 100. The sulphate of ammonia plats showed a pH value of 4.47, dried-blood plats 4.61, nitrate of soda 5.14, and manure 5.28. Plats receiving only potash and phosphorus showed a pH value of 5.15.

In lysimeter experiments at the Tennessee station there was no recovery of nitrogen in the drainage of deep cylinders. Where there was recovery, the nitrogen was in the form of calcium and magnesium nitrates. There was no decline in the nitrogen content of the cropped as compared with the uncropped soils.

At the Texas station the correlation factor between the nitrogen content of the soil and the nitrogen taken up by the crop was found to be 0.653 ± 0.029. The ratio between the amount of nitrogen taken up by the first crop and the amount of nitrates available in the soil was 0.708 ± 0.025, and between the nitrogen removed by the crops and the decrease in nitrification of the soil, 0.68 ± 0.029.

Phosphates.—At the Wisconsin station, in pot cultures with alfalfa, it was found that some soils that show a rather high phosphorus content respond to the addition of phosphates. In some soils there was no response to calcium or potassium until phosphate was added. The studies indicated that the less acid the sap of the plant the greater is its power to draw phosphorus and potash from dilute solutions.

In a test, at the Arkansas station, of rock phosphate of different degrees of fineness both corn and oats were somewhat earlier with the finely ground rock. There was an increase in phosphorus in the corn plants on plats receiving phosphate. The addition of lime decreased the availability of the phosphoric acid, and a liberal supply of organic matter appeared to increase it. Tests at the Kentucky station showed a wide difference in the behavior of phosphates in different kinds of soils, with and without lime.

In a comparison extending over nine years, the Missouri station found acid phosphate, steamed bone meal, and raw rock phosphate, applied in equal money values with manure, to give approximately equal crop increases.

Potash.—The Illinois station found that both buckwheat and spring wheat showed a marked ability to utilize potash-bearing minerals. Shale and leucite produced considerably more dry matter than orthoclase or raw alunite. At the Ohio station, in comparative tests of ammonium sulphate, sodium nitrate, calcium sulphate, and monocalcium phosphate, ammonium sulphate was most active in making soil potash soluble. Ignition increased the solubility of the potash. Extraction with one-hundredth normal nitric acid showed availability agreeing well with that indicated by field and pot experiments. In sand cultures with buckwheat at the Pennsylvania station, adding calcium carbonate and sulphate to orthoclase increased the amount of potash in the plant tissue. Sodium chlorid increased the dry weight of plants, but seemed to reduce the available potash. Sodium sulphate did not affect the availability of potash or the dry weight of plants. The Texas station found a relation between the potash removed by crops and that dissolved from soil minerals by fifth-normal nitric acid.

Manure.—Applications of manure at the rate of 8 tons per acre materially increased the amount of soluble potash in the soil in experiments at the Iowa station. Tests by the New York State station showed acid phosphate to be a good preservative of manure, whereas gypsum seemed to have no good effect and under certain conditions was harmful. Dried peat gave fairly good results but may be too expensive. Straw added to rotted manure gave poor results, the manure losing nitrogen rapidly, and no preservative action was noted. The mixture had a depressing effect on the crop, as if there were toxic action. Some indications were found of a toxic agent in the straw extracts when applied to wheat and barley seedlings.

FIELD CROPS

Wheat.—In a study of the chromosome number of Triticum species, the Maine station found einkorn or *Triticum monococcum* to have seven pairs of chomosomes, and the emmer group, including *T. durum*, *T. turgidum*, *T. polonicum*, and *T. dicoccum*, 14 haploid chromosomes, whereas the bread wheats, including *T. vulgare*, *T. compactum*, and *T. spelta*, have 21. Species crosses were fertile if the chromosome numbers were the same, but partially sterile if different. In crosses between species with 14 chromosomes and those with 21, 14 pairs of chromosomes underwent a regular reduction, while 7 were assorted at random. Environmental studies with wheat at the New York Cornell station showed that within pure lines there was no particular genetic change, whether this crop was grown in poor or in rich soil. Inheritance studies at the Washington station indicated that the horny endosperm of Turkey wheat is transmitted as a unit character, the segregation taking place in the heads of the F_1 plants.

Investigations at the Colorado station showed that cold water in early irrigation retarded the growth of grains and that irrigation after blossoming lowered the yield. The highest yield was obtained when irrigation was applied at the time of jointing. Late irrigations gave better filling out of the grain and better quality. With corn the best results were obtained by irrigating at the beginning of tasseling, but early irrigation was found to be necessary to start the crop off well.

Studies on the sterility of small grains at the Arizona station showed that varieties having the most tillers had the greatest number of sterile spikelets. It was also noted that the heavier and longer the straw and the heavier the spike, the fewer the sterile spikelets. Anything that stunted the plant increased sterility.

Milling tests at the North Dakota station with hard red spring wheat varieties showed, with one exception, no significant difference in loaf volume. The new rust-resistant variety, Kota, was a little higher than Marquis in loaf volume, water absorption, and gluten content, but a little lower in texture and color. Durum varieties were distinctly inferior to hard red spring varieties in breadmaking quality, especially loaf volume and texture, The hard red spring wheats showed practically no change in baking quality after storing, but the durum wheats showed first a decrease in loaf volume, then a large increase, finally giving a volume larger than in the initial baking. Durum wheat doughs from stored samples lost the stickiness characteristic of durum flour. In milling tests at the Kansas station the best results as to keeping quality and grinding were obtained with 15.5 per cent moisture and a temperature of 20° to 25° C.

The Montana station found that frost injury lessened the amount of proteins and increased the amino compounds. Aging the wheat or flour after frosting reduced the amino compounds and greatly improved the quality of the loaf. It was concluded that the value of frosted wheat is almost always higher than the grades given it in the grain trade.

Tests at the Idaho station showed that available nitrogen in the soil is an important factor in the formation of protein in wheat throughout the entire cycle of plant growth, and that it also has an effect on the yield. Climatic factors, especially moisture, greatly influence the protein content when sufficient nitrogen is available.

Selections of Federation and Hard Federation from Australian wheat varieties outyielded early Baart more than 20 per cent at the Oregon station. Pure line selections of wheat were found that are immune to both species of stinking smut, although thus far the immune strains are not equal in yield to the leading commercial strains. Hard Federation spring wheat outyielded Marquis at the Montana station for two years, 7 and 8 bushels respectively. It has excellent milling and baking qualities. The station has developed a selection of Kharkof under the name of Montana 36, which in a 6-year trial has yielded 2.4 bushels per acre more than any other variety with which it was compared. It is being extensively grown.

Oats.—The Iowa station developed and distributed a new variety of oats, the "Iogren," from selections of Green Russian, which it outyields by 7.6 bushels per acre. The grain is a bright golden yellow, but it is considerably later than Iowar. The Kansas station secured selections of Burt oats that remained resistant to smut for four generations. The relation between amount of smut and yield was not always found to be a direct one. Other factors, such as early maturity and plant kernel characters, were in some cases more potent than smut in determining yield. A strain of oats was produced by the Wisconsin station, named the "White Cross Oat," which has white kernels much larger and heavier than those of other varieties. In 1922 it yielded 62.8 bushels per acre. Lodging appeared to be dependent largely upon the variety used as seed; but the rate of seeding

also exerted considerable influence, lighter seedings showing the least lodging.

Barley.—Crosses at the Kansas station between Nepal, which is a white, hooded hull-less barley, and Gatami, a black-bearded hulled variety, proved to be early, did not shatter so readily as Gatami and gave a higher yield than Nepal. The Minnesota station found no cumulative effect in continuous selection of barley in pure lines for earliness or yield. An improved beardless barley was developed at the Tennessee station. At the Utah station it was found that barley, like other small grains, requires not more than 15 to 17 acre-inches of water, and that water should first be applied when the plants have five or six leaves.

Corn.—Inheritance of chlorophyll color in corn apparently involves a linkage between chlorophyll and anthocyanin and between chlorophyll factors and some endosperm characters, according to conclusions reached at the Wisconsin station. Decreased vigor following inbreeding of sweet corn appeared, in studies at the Maine station, to be due to inherited characters and not to consanguinity or inbreeding per se.

Diseased seed corn produced weak seedlings, which were very susceptible to the cold weather in early spring plantings, in experiments at the Illinois station. The ear characters that proved most significant as an index of diseased condition and low yielding ability were shredded shanks, starchy kernels, brown shanks, or shanks with brown bundles. Soil enrichment did not overcome the handicap of diseased seed. It was found possible, at the Kansas station, to fix resistance to smut by inbreeding for three or four years. Strains resistant in Kansas proved to be even more resistant in Connecticut, and resistant varieties from the latter State showed from 30 to 40 per cent of infection in Kansas. Strains resistant in Kansas were still more so in Indiana. Self-fertilization as it occurs ordinarily in the field does not seem to exceed 1 per cent, according to observations by the Nebraska station. The continuous natural segregation and recombination of the elemental hybridizing characters, together with the natural element of survival of the fittest, accentuated by man's repeated selection of well-developed ears for seed, seem to account in a large measure for the inherently high productivity of field corn as now grown. In a four-year test of F_1 hybrids between pure lines, the average yield surpasses the original corn 17.2 per cent, while the most productive hybrid excelled the original by 30 per cent. Pollinating a prolific stalk with pollen from barren stalks gave an inherited barrenness in the first generation of about a 1:3 ratio in experiments at the South Carolina station. If the barren stalks were detasseled and seeds selected from prolific stalks, barrenness was eliminated. A double-crossed Burr-Leaming hybrid developed at the Connecticut State station outyielded all other station varieties of corn. Its outstanding qualities are uniformity in yield and upright stand. It requires from 120 to 130 days to mature.

Attempts at the Louisiana station to establish a pure yellow descendant by crossing yellow strains of Calhoun Red Cob and Stewart's Yellow Dent corn resulted in the establishment of the yellow, apparently as a pure character. Studies at the Virginia station showed that within a variety of corn early maturity appears to be correlated with high yield, but the controlling factor in both yield and earliness

seems to be the food supply. At the Wisconsin station selections of Golden Glow made by ice-box germination tests developed a strain of corn that germinated and developed during the cool weather of spring or early summer. There is great demand for such a strain both in the Northern States and in Canada. In order to maintain this cold-resistant character the strain must be grown in the North. This station also found that the use of fertilizers in the hill may increase the salt concentration of the sap sufficiently to enable it to withstand a lower temperature than unfertilized corn.

Sorghums.—Two distinct varieties in the character of the stalk of sorghum were secured at the Kansas station in a cross between Red Amber cane and feterita, one being juicy and one pithy, the latter proving to be entirely smut-free. The average yield of the juicy stalked plants was 7.18 tons per acre of fodder, with a grain yield of 57.64 bushels, and of the pithy stalked plants 6.31 tons of fodder and 62.48 bushels of grain. Results obtained with this cross showed that the white palatable seed, which will thresh free from the glume, and the smut resistance of feterita can be combined with the juicy stalk of Red Amber sorghum. It was found that many of the sorghums, especially milo, feterita, darso, and Freed sorghum, are very resistant to kernel smut. The Texas station developed a strain of dwarf feterita by pure line selection that is about a week earlier than any other known variety and possesses unusual drought-resistant qualities.

Forage crops.—Alfalfa was practically killed in experiments at the Kansas station when it was cut in the bud stage; when cut in the one-tenth bloom stage much grass came in; that cut in the full bloom and seed stages remained in excellent condition. From the feeding standpoint the earlier cut alfalfa was the better, and the station therefore recommends cutting in the one-tenth to one-fourth bloom stage. Experiments at the Wisconsin station showed that for the Northern States two cuttings only, at or very near the full-bloom stage, not only yielded more hay but kept the stand in a more vigorous condition. The weakening effects of early cutting were shown not only in a lower vigor but also in the crop being more susceptible to winter injury. Late fall cutting is therefore thought to be a dangerous practice as it greatly increases the liability of winter killing and reduces the vigor of the following season's growth. New seedings of alfalfa were much hardier than old stands. In experiments on the value of sulphur for alfalfa, the Oregon station found that an application of 100 pounds per acre seemed to be sufficient for about four years. The amount of sulphur received in rainfall was found to be only 4 or 5 pounds a year, whereas 40 pounds were lost by percolation.

In a study of legumes as soil builders at the South Carolina station, corn following corn with velvet beans yielded 42 bushels per acre as compared with 15 bushels on an adjoining plat of corn following cotton. With a cover crop of rye and vetch sown in cotton middles in October and turned under in May, more nitrogen was supplied to a corn crop following than it could utilize, as shown by the fact that there was no response to an application of nitrate of soda on part of the field.

Bacteria occurring on the roots of 10 species of legumes were found by the North Dakota station to be still in a very vigorous condition

after 10 months' drying in the laboratory. The Washington station found that on exposure of inoculated seed to sunlight a very high percentage of bacteria is killed during the first few days but that an appreciable number was found to be alive on the seed even after four months' exposure to sunlight. Of 60 soils of the State examined by the Colorado station for nodule formation, 70 per cent showed a natural inoculation for alfalfa.

One of the most successful ways of growing Hubam sweet clover, according to experiments by the Iowa station, is to seed it with small grain in the spring, thus producing a crop of seed the same year before frost. This crop gave best results as a green manure crop following small grain. The Louisiana station found the large yellow sweet clover *Melilotus officinalis* to be an annual in the southern part of the State but a biennial in the northern part. A yield of 31,272 pounds per acre of green material was secured, containing 104 pounds of nitrogen exclusive of that in the roots. Turning under the crop increased the yield of the following crop of sugar cane from 3 to 10 tons per acre. Annual white sweet clover yielded the same amount of hay in one cutting as biennial yellow and more than biennial white. The Montana station found that sweet clover will carry fully twice as many head of livestock per acre as any other crop now being used.

The Washington station found that with moderate rainfall biennial sweet clover stayed green late in the fall the first year and made abundant growth early in the spring of the second year; so that, if two fields were maintained, one seeded each year, pasture hay was available throughout almost the entire season. The North Dakota station found that unless properly managed sweet clover may become a rather pestiferous weed when grown in regular rotation, and that it is safest to grow it in short rotations such as a three-year one of grain, sweet clover, and a cultivated crop. The principal control measure for killing out volunteer sweet clover is late spring plowing. A sweet clover pasture showed a carrying capacity of 28 sheep per acre for a period of four months; and, except for a shortage of water for about two weeks, the pasture carried four cows per acre.

Vetch was found by the Oregon station to withstand the winter best when planted moderately early in the fall. Spring planting was not satisfactory. Best results as a seed crop followed seeding at the rate of 60 to 80 pounds per acre. It was found to fit in well in many rotations. Pollination studies showed that the varieties are largely self-sterile. Trial for a number of years proved Hungarian vetch to be of great value, being suited to wet, unfavorable conditions. It was found to yield more hay, silage, and seed than other vetches, to shatter seed less readily, to be more resistant to aphids and a good bee plant.

The sunflower crop was found by the Maryland station to draw about as heavily as other crops upon the nitrogen of the soil, less heavily than grain upon the phosphorus, and more heavily than other crops upon the potash. Owing to its heavy growth it exhausts unduly the plant food of the soil, and should therefore be grown in rotation with other crops. The North Dakota station found that the dry matter reached a maximum in sunflowers during the first week in September, when the plants are about 80 per cent headed out. The Wisconsin station showed that when sunflowers were as close together as 6 inches in the row there was a pronounced drying up of the lower

leaves before time for harvesting. Spacing of at least 8 to 12 inches is therefore recommended. The relative proportion of leaves increased as the planting spaces increased up to 12 inches, after which no further gains were obtained. Results of tests at the Wyoming station indicated that sunflowers should be planted several weeks earlier than has been the practice. The plant was found to be able to stand light spring frost and can therefore be planted much earlier than corn. Compared on an acre-yield basis, sunflowers were superior to corn. In experiments at the Oregon station, oats and vetch yielded 16 tons per acre, sunflowers 14.7 tons, and corn 8 tons. Silage made from the sunflowers was lacking in palatability. Oat and vetch silage was richest in protein and lowest in labor cost.

At the Georgia station sweet potato vines made a silage of a peculiarly pleasant odor, which was readily eaten by stock. Japanese cane made a silage as good as corn silage, but Napier grass did not make a silage of good quality. Cotton stalks made a silage which kept well but the stock left about half of it in the form of coarse woody material.

The Kansas station found that on pasture which had been burned over each year for four years there was an increase of 21 per cent in grass, as compared with an increase of 7 per cent on unburned pasture. Burning caused a change in the type of vegetation, weeds showing a tendency to decrease on the burned area and to slightly increase on the unburned. The South Carolina station succeeded in seeding cut-over land to pasture with carpet grass and Lespedeza. Some preparation by disking, and small applications of nitrate of soda and acid phosphate, hastened the development of pastures on these poor lands very materially. At the Nebraska station, pasture that was not manured carried 8 sheep per acre on a 102-day test, while manured pasture carried 16 sheep per acre. The fertilizer tests on grass plats at the Pennsylvania station showed, after a number of years, that mixtures high in nitrogen favored the grasses which crowded out the clovers; whereas on plats receiving little nitrogen the clovers were relatively abundant. Complete fertilizers with a high percentage of nitrogen gave the highest average yields of hay.

Of the cultivated grasses and clovers tested at the Nevada station for the improvement of wild hay lands, the only one giving promise of value was the common biennial form of sweet clover. This was found to root well under somewhat unfavorable moisture conditions and did not drown out readily under excessive flooding of the soil. It also proved to be rather more resistant to alkali than other plants and grasses tested.

The Florida station found Bahia grass (*Paspalum notatum*) to be the most promising pasture grass of recent introduction. Warm weather is essential for best germination of the seed, which is poor when it is not grazed or mowed. It shows a wide range of soil adaptation. Subterranean clover (*Trifolium subterraneum*), introduced from Australia, was tested with good results on flatwoods soil as a winter annual.

Potatoes and root crops.—In a comparison at the Nebraska station of potatoes grown on dry land and under irrigation, it was found that taking the yield from dry land seed as 100 per cent, seed from plants irrigated one year yielded 85 to 90 per cent; irrigated two years, 60 to 75 per cent; three years, 40 to 65 per cent; and four

years generally less than 40 per cent. A few irrigated strains showed a tendency to maintain their vigor fairly well under irrigation. Potatoes grown continuously on the same land became so scabby as to be unmarketable. In a six-year rotation they were generally free from scab, while in a four-year rotation the amount of scab was considerably geater. Hill selection at the Utah station increased the acre yield of potatoes from 60 to 90 per cent. Selected stock grew more quickly, gave better stands, and produced higher yields of better quality, giving smoother and more uniform tubers and fewer culls.

In a test of size of seed piece at the Oregon station, using 20 bushels of seed potatoes per acre, cut into 1, 2, and 3 ounce pieces, larger yields were secured from the smaller pieces planted closely, 1½-ounce pieces being the most economical size. One-and-one-half-ounce whole-blossom end pieces yielded more marketable potatoes than similar-sized split-blossom end pieces. Planting 5½ inches deep gave higher yields than planting 3 inches deep. Treatment after cutting seed potatoes gave a reduced yield as compared with treatment before cutting in experiments at the North Dakota station. Potatoes soaked in water showed injury after a comparatively short time, dependent upon the temperature of the water. In spacing tests at the Wyoming station, including hills from 6 to 36 inches apart, the 6-inch spacing gave the highest yield of marketable tubers (305 bushels per acre), 36-inch giving only 129 bushels. Hills next to missing hills did not give definitely larger yields than normal hills. Planting one-fourth of medium-sized tubers gave the largest yield per acre (246 bushels) and one-sixth of large-sized tubers gave the lowest yield (130 bushels per acre). Large plants gave the largest yield of tubers per hill and also the largest tubers. Four stems per hill gave the greatest yield of marketable tubers per hill, but the hills with single stems produced the largest tubers.

At the Kentucky station the loss in storage at 60° to 85° F. of sweet potatoes the vines of which had been cut before frost was 4 per cent. When the vines were cut immediately after a freeze no loss occurred; when cut five days after a freeze the loss was 88 per cent. Potatoes wrapped in paper sustained a loss of 20 per cent, compared with a loss of 12 per cent in case of unwrapped potatoes. Tests at the Mississippi station showed that the lowest temperature sweet potatoes can safely stand after being cured is 28° F.

The Colorado station found that when soil nitrates reached 400 pounds per acre there was a decrease in sugar content and decline in quality of the sugar beet, as well as an increase in susceptibility to disease. The specific effect of excessive nitrates appeared to be an increase in the noncrystallizable sugars. In tests at the Utah station, beets 1 foot apart in the row gave a higher yield than any other distance of planting; and one or two small irrigations in alternate furrows early in the season, followed by irrigation in every furrow for the balance of the year, gave best results.

Cotton.—The name "Louisiana No. 1" has been given to a long-staple cotton developed by the Louisiana station from a cross between Dixie and Louisiana Hybrid No. 143. This has a staple of 1.5 inches, with a good percentage of lint. The yield of cotton following corn and soy beans planted together was approximately 100 per cent greater than that of cotton following corn alone.

Breeding and selecting for high and low oil and protein strains at the Arkansas station resulted in strains that show a difference of 4 to 5 per cent from the average, or about 9 per cent between extremes. The highest percentage of oil and protein obtained is about 30, but it is believed that these high percentages will quickly go down without constant selection. Results obtained at the South Carolina station indicate that the oil content is largely dependent on other factors than heredity. A difference of 10 per cent in oil was noted in the same variety grown in Arkansas and Tennessee. All varieties showed a higher oil content in Florida than in Tennessee. The oil content of the same variety grown on different plats often varied as much as those of different varieties. No decided correlation was found between the kind and amount of fertilizer applied and the oil content of the seed. The Texas station reports that earliness is found to be correlated to the putting out of the first lobed, mature-shaped leaves, which is helpful in the roguing of this characteristic.

Tobacco.—The Kentucky station found that in White Burley tobacco the nitrogen content of wrappers was different from that of fillers and smokers, as was also the nicotin content. Although nicotin content of the best of a given grade was usually much larger than that of the common, there was little difference in the total nitrogen content, suggesting that the common types may have nitrogen in some form which goes to make the tobacco inferior. The White Burley tobacco contained much more nitrogen as nitrate and less nicotin than the dark tobaccos. The ash of White Burley was found to contain more phosphorus, potassium, and calcium, and less silicon and magnesium, than that of dark tobacco. Six strains of White Burley tobacco developed by the station proved to be earlier, more uniform in growth and type, and resistant to root rot when grown in diseased soil, with as good or better quality than that commonly grown. Two selections of Vimont Kelley White Burley were found which were practically immune to root rot. The Ohio station reported that two improved varieties, Montgomery seed leaf and Tall Zimmer, were distributed and raised by pratical growers with encouraging results.

HORTICULTURE

Fruits.—Yellow Newtown apples picked late in October developed "fruit pit" and later broke down on storage in experiments at the Oregon station. Fruit picked early in October held up well, but did not attain such large size. October 15 appeared to be the most practical time to pick this variety in Oregon. Esopus Spitzenburg picked October 6 was of better keeping quality and flavor than those picked on October 18. Anjou pears attained best size and quality when picked as late as October 1 to 8. On an average this fruit increased from $\frac{10}{16}$ to $\frac{13}{16}$ inch in circumference during the last month of growth, and shrinkage in storage was less in late picked than in early picked fruit. The coloring was also better.

The effect of aeration in storage by means of electrical fans varied with the different varieties of apples in experiments at the Iowa station. No soft scald occurred on Jonathans where they were well aerated, but aeration was not so efficient in preventing scald on Grimes Golden. Wrapped apples scalded very little. A comparison of com-

mon paper, waxed paper, tinfoil, and oiled wraps showed that scald was practically controlled in all cases where oiled wraps were used but not in the other cases. Grimes Golden stored at optimum maturity showed very little scald.

Many varieties of apples mature before they are well colored, according to the Washington station. Apparently such factors as color of fruit, color of seeds, size of fruit, or ease with which it breaks from the stem, or a combination of these can not be used as a safe guide in determining when varieties should be picked.

For practical purposes all commercial apple varieties are self-sterile, but most varieties are interfertile, according to results reported by the Maine station. Bumble bees were found to be an important factor in effecting cross pollination. There was high correlation between size of nursery trees and ultimate size after six years in the orchard. The great variability found in a study of 881 Ben Davis trees was attributed primarily to differences in soil, variable root stocks, and differences in individuals of a clonal variety due to bud nutrition. The first two factors were influential in causing differences in yield.

In a test of a large collection of all known species and varieties of pears of this and other countries, the Oregon station found a very small percentage resistant to blight, but very promising as blight-resistant stock on which to graft commercial varieties. Seedlings of even the common varieties varied greatly in resistance, only a small percentage proving immune. It was found that the time of picking did not greatly influence the keeping quality, except that fruit picked very early should be partly ripened under more humid conditions and for a longer period than those picked later. Fruit kept three months longer when given a delayed storage of 10 to 15 days at ordinary temperature than when given 12 to 15 days of refrigerator car temperature at a humidity 60 to 70 per cent.

The Oregon station found that Bing, Napoleon (*Royal Anne*), and Lambert cherries are intersterile, and recommends planting one Black Tartarian to every 20 trees of these varieties.

The California station found that since sour stock is apt to vary greatly, only selected strains should be used for propagation of citrus fruits. The use of arsenical sprays on citrus trees was found to reduce the acid content of the fruit and make it insipid. The internal decline of lemons was found to be a physiological trouble, related to the breakdown of fruit as it nears maturity. No organism was found in connection with the trouble. The Florida station found in a test of fertilizers that citrus trees receiving no potash had more sugar and less acid than those receiving potash, there being also an increase in invert sugar in the no-potash trees. The no-potash trees were, however, smaller and produced smaller fruit than those receiving potash. The Arizona station showed that the use of summer cover crops was a means of preventing premature shedding of leaves and that clean cultivation during the winter lessened winter injury to the citrus trees.

In experiments on the drying of prunes the Oregon station found that temperatures in the drier as high as 180° F., with a high humidity, were injurious. The best quality was obtained at a temperature of 150°, a humidity of 15 to 20 per cent in the drier, and the movement of air through the drier at the rate of 75 feet per minute.

In a study of the viability of grape pollen the North Carolina station found that pollen of the variety tested kept its viability for 15 days, and it was concluded that with proper drying and packing it might be sent long distances and still be effective. The South Carolina station obtained the best results by letting two canes come up from the ground, training one to the first wire and the other to the second wire of the trellis, thus giving two terminals and allowing more light on the lower arms.

Studies of strawberries at the Missouri station indicated that nutritive conditions in the soil in the spring, immediately preceding and during the fruiting season, are of less importance in influencing yield than are the conditions immediately preceding and during the period of fruit-bud formation. The Oregon station found that heavy applications of nitrogen and comparatively low applications of potash produced the largest yields. Where much potash was used, small, seedy berries resulted; but with excessive nitrogen the berries although large were inclined to be soft, especially during a short hot ripening season.

The factors directly concerned in the jellying of fruit are, according to the Delaware station, the pectins, sugars, and acids. Jellying depends more on the H-ion concentration than on the total strength of the acid. The lowest jellying point was found to be at approximately pH 3.4 and the optimum point at pH 3.1. At pH 4 and above it was impossible to make a jelly. By determining the H-ion concentration of the juice and its pectin content, the material to be added to make it jelly is easily calculated. Most of the fruit juices examined had a concentration of about pH 3.

Nuts.—Pollination of the filbert was found by the Oregon station to take place in January or February, but the act of fertilization did not occur until June. All varieties observed were self-sterile. In investigations on walnut die-back at the California station it was found that trees in orchards in which the soil moisture was reduced to the hygroscopic point during the ripening period and continued to the middle of the dormant period escaped injury. If rains came they suffered from die-back.

Vegetables.—Home-grown bean seed, acclimated through several years of growing and selection, produced mature string beans two weeks earlier than seed from the same variety obtained from various seed houses in experiments at the Montana station.

An increase in yield of Lima beans was obtained at the Illinois station by inoculating with pure cultures of the nodule organism of cowpeas.

The failure of lettuce to head was corrected in experiments at the Kentucky station by drenching the soil and manure with formaldehyde.

The best germination of lettuce seed was secured at the Minnesota station by soaking the seed for six hours and then exposing to indirect sunlight at a constant temperature of about 73° F.

Two wilt-resistant varieties of tomatoes, originated by the Louisiana station, the Louisiana Pink and Louisiana Red, are widely distributed over the State and are giving generally good results.

105313—23——3

The maturity of tomatoes was hastened in tests at the New Hampshire station by the application of acid phosphate. Manure increased the yield but did not hasten maturity. Potash had no appreciable effect upon maturity.

The North Dakota station found that low temperatures were unfavorable for the winter storage of squashes.

Ornamentals.—The tamarisk, in trials at the Arizona station, withstood a temperature of 12° F., but should have no irrigation after September 1. It thrives in alkali soil, and the wood is close-grained and hard. The species *Tamarix articulata* has proved very valuable for windbreaks for citrus orchards, as it makes a very rapid growth. The pistachio tree was found to be tolerant of alkali and exteme heat and is not injured by a temperature as low as 6° F.

Pink-flowered hydrangeas became blue when the H-ion concentration was below 6.4 in tests at the New Jersey stations.

A very promising cross of the American Beauty rose with native species, which is very hardy, with about 50 well-developed petals, was secured by the South Dakota station.

Orchard management.—The New Hampshire station found that if an orchard is thoroughly cultivated, the use of a complete artificial fertilizer does not give sufficient increase in yield the first 10 years to be profitable under New Hampshire conditions. The chief deficiency in a sod orchard was found to be nitrate nitrogen, which can be efficiently supplied as a chemical fertilizer, thus making it possible to extend the orchard industry to lands which are not suitable for cultivation.

Applications of nitrogen, as nitrate of soda or in the form of a cowpea cover crop, were very profitable with apples in experiments at the Illinois station. Mulching with grass and legumes grown between the trees was more profitable than clean cultivation. With peaches, clean cultivation and heavy fertilizing with nitrogen and potash gave the best results. Cowpeas proved very detrimental to the growth of the trees and the yield of fruit unless fertilized with potash.

Injecting nitrates into the roots of trees gave quick response at the Ohio station, and by inarching small trees on larger ones it was possible to feed one tree through the roots of another.

Nitrates increased production 300 per cent in neglected sod orchards the first year of application in experiments at the Indiana station. Tests extending over 11 years showed that apple trees under cultivation with cover crops and a heavy straw mulch produced three to four times as much fruit as trees in sod, but when nitrate of soda was applied there was a marked increase in tree growth on the grass plats over the cultivated plats. The root system was largest and extended to a greater depth in the tilled soil than in soil under straw mulch or grass. Trees in sod were seriously dwarfed in both roots and tops.

In an apple orchard in timothy sod, at the New York Cornell station, nitrate of soda up to 900 pounds per acre had very little effect after a few months, but in a cultivated orchard it had a marked effect which increased in proportion to the amount applied. Like results were obtained in cherry and plum orchards.

Continuous clean cultivation of irrigated apple orchards was found at the Washington station to exhaust the organic matter and to

develop a hard, compact subsoil immediately below the depth of the plowed layer, as well as a very poor physical condition of the surface soil. The compact condition interfered with the penetration of moisture and the efficient use of irrigation water. The temperature of the soil under alfalfa was found to be 64° F., while in bare fallow it was 96°. The soil temperature during July and August was 8° to 10° lower under permanent alfalfa than under bare fallow. Similar studies at the Arizona station showed that soil under a cover crop was 6° to 8° cooler than cultivated soil. The latter showed 40 per cent less evaporation and a higher humidity. The temperature of the soil under a cover crop was 2° or 3° higher, and its humidity in summer was 10 to 12 per cent higher than that of the atmosphere. The Montana station obtained the best results by clean cultivation of young apple orchards or by intercropping with a cultivated crop for a few years and then putting in a clover cover crop. The inadvisability of clean cultivation year after year was demonstrated.

Hardiness and winter injury.—Environmental conditions during freezing, such as length of exposure to low temperature, the rate of temperature fall within limits which are possible under field conditions, and the rate of thawing after freezing are, according to the New Hampshire station, of relatively small importance in case of apples, the amount of injury depending most largely upon the degree of temperature to which the roots are subjected. Roots exposed to a minimum temperature of 45° F. for one-half hour were 27 per cent injured; exposed for 4 hours, 31.5 per cent; and for 18 hours, 43.5 per cent. When the drop in temperature was sudden, there was more injury than when it was slow. Injury was greater in moist than in dry sand. The part of the root just inside the cambium layer was found to be most susceptible to winter injury, but growth was not seriously affected unless the outer (phloem) cells were also injured.

At the Arkansas station apple trees in which a good growth in the fall was maintained by the application of nitrates escaped much of the frost injury in the spring. The pollen was not hurt by frost injury sufficiently to destroy the pistil and ovary. There was much difference in the viability of pollen from different varieties.

The Missouri station found hardiness to be dependent upon the water-retaining capacity of the plant cells, an increase in which enables the cells to retain a larger proportion of their moisture content in an unfrozen condition. A relation was found to exist between water-soluble pentosans and the water-holding capacity.

The buds of the hardy varieties of peaches were found by the Maryland station to contain less water than tender varieties. The moisture content was found to increase early in the spring; but this increase was dependent upon the temperature, no increase taking place below 43° F. The buds appeared to get their moisture from the roots rather than from the twigs.

Winter desiccation of fruit trees is, according to the Washington station, serious at times under certain semiarid conditions; and as it occurs only where the humus content of the soil is low and the nitrogen quickly exhausted, it is believed that the latter element is the limiting factor in its occurrence. It is characterized by rosette leaf formation and chlorosis in the new growth, chemical analysis showing this abnormal growth to be high in ash and with abnormal per-

centages of nitrogen. When infected twigs were grafted into normal wood they outgrew these conditions. It was found that growing leguminous cover crops in the orchard tended to correct the trouble.

Pruning.—The necessity of regulating pruning practices to the varied habits of the tree and the hazardous nature of most summer pruning practices were emphasized in studies at the Oregon station. No form of summer pruning was found as favorable to tree growth and spur development as winter pruning.

The amount of pruning of mother shoots had little influence upon the total amount of new laterals produced in the following season in experiments at the California station. Fruit spurs were commonly more abundant upon unpruned mother shoots than on those pruned the previous winter. A new method of pruning young olive trees was worked out, which hastens the development and shortens the time of coming into bearing.

Rest period.—The Missouri station found the rest period to begin when there was a maximum H-ion concentration of the sap. Phosphorus increased during the winter in the buds faster than nitrogen and H-ion concentration, and then began to drop, the phosphorus apparently neutralizing the acidity. The rest period, however, was apparently not determined by the H-ion concentration.

PLANT DISEASES

Cereal diseases.—The Minnesota station reported additional biologic strains of cereal rusts as distinguished by their reaction to different host species, making a total of 37. Progress was made in the development of strains of wheat resistant to rust. The uredospores of black rust were found to retain their viability until late in March, while the first infection of barberry by sporidia from teleutospores did not appear until May, and on wheat still later.

Investigations at the Nebraska station showed that the uredospores of the stem rust of wheat remained viable for 16 weeks at 41° F., with a humidity of 50 per cent. No germination was evident when the spores were kept for two weeks at 86° F., and there was only slight germination at 77° F. No viable spores were found late in the winter or early spring under natural conditions.

The Idaho station found over 60 wild grasses to be hosts for the stripe rust of cereals. No alternate host plant was found. The summer stage overwintered in wild grasses and winter wheat in Idaho.

At the Indiana station five varieties of wheat of economic value were found to show fairly uniform rust resistance when tested in a number of localities and States, all being of the Turkey type, not well adapted to the eastern United States. The æcial stage of the rust was produced in the field. A number of strains of rust were found, some varieties of wheat being resistant to one strain and not to another.

The Indiana station found the æcial stage of the leaf rust of barley on the Star-of-Bethlehem, which in some sections has escaped from cultivation and become a weed.

The Idaho station established the fact that the temperature and moisture content of the soil have a very definite effect upon the amount of smut present in the crop at harvest. The amount of

infection increases as the amount of moisture increases up to saturation. The highest infection developed at the lowest temperature.

The method of treating the seed with dry copper carbonate dust mixed with a little lime, devised by the California station, is being widely practiced. Tests at the Washington station showed that 2 ounces of copper carbonate to a bushel of seed caused no reduction in germination but rather improved it, treated seed showing a more rapid germination, a more vigorous growth, and greater freedom from winter injury than untreated seed. One-half ounce of carbonate gave nearly as good protection as 2 ounces, and 3 ounces gave slightly better results. The maximum percentage of smutted heads from treated seed was 5.41 and from untreated seed 64.4. Copper carbonate gave better protection against smut from soil contamination than formaldehyde and was equal to or better than bluestone treatment.

The Oregon station found a large amount of seed injury due to treatment with formaldehyde or copper sulphate for smut control, whereas dusting the seed thoroughly with powdered copper carbonate showed practically no injury and the results as regards smut control appeared satisfactory.

In a state-wide three-year survey, the Virginia station found that three bearded varieties of wheat—Stoner, Red Wonder, and Fulcaster—showed much greater infection with loose smut than the beardless varieties—Harvest King, Fultz, and Leap.

The Idaho station showed that low soil temperatures and a fairly high percentage of moisture in the soil are both conducive to infection with stinking smut or bunt. Most infection occurred at temperatures ranging from 9° to 12° C. (48° to 54° F.), with 22 per cent of soil moisture. Some infection occurred, however, during germination at a temperature of 25° to 28° C. (77° to 82° F.). Very little infection took place from spores which had been in the soil one month under the above conditions. Spores lost their viability in moist soils repeatedly cultivated. It was found that under Palouse conditions infection took place after the plant emerged from the soil. No dust treatment gave as good control of the disease as the standard bluestone dip treatment

At the North Dakota station in several hundred isolations from seed and seedlings of wheat, barley, and rye affected with scab, *Gibberella saubinetii* was found in every case, and in no case was *Fusarium culmorum* found. The embryo of the grain was the first part infected, the infection later extending to the endosperm. Careful cleaning and grading of the seed reduced the disease.

At the Missouri station the limiting acidity for seedling infection by *G. saubinetii* was found to be pH 5.5. This is not an unusual soil reaction, and is one to which soils could easily be adjusted.

In seed treatment for wheat blight, at the North Dakota station, good results were obtained with parachlorphenolate of mercury, commercially known as chlorophol, which apparently penetrated the seed coat and reduced the amount of infection. Infection in black-pointed grains was found to be due to a species of Helminthosporium closely resembling *H. savitum*. The embyro itself was found to be penetrated by the mycelium, and when moisture was supplied the fungus formed enlarged lesions in the primary roots before they broke through the seed coats. Spores of the fungus were frequently found

under the seed coat in these lesions. Such grains frequently failed to germinate.

The Kansas station isolated the organism from root rot or take-all of wheat and identified it as *Ophiobolus careceti* with *Wojnowicia graminis* commonly associated with it. The pathogenicity of the latter was not determined. It was apparently carried over in the stubble and probably in the soil. A rotation with cereals every four or five years seemed to offer the best control. Studies at the Indiana station showed that the disease may persist in the soil for three years. Some varieties were found that were immune to the trouble.

The Tennessee station found that the following fungi are very commonly associated with wheat seed in the order mentioned: Alternarias, Helminthosporia, and *Gibberella saubinetii*. The fungi most commonly associated with wheat roots were Helminthosporia and Fusaria.

Corn diseases.—Studies at the Indiana station showed that potash in the form of kainit tends to correct corn root rot on acid muck soils, but no benefit was derived from applications of lime or phosphate on such soils. On the other hand, the application of lime and phosphorus to an Indiana clay soil apparently affected the absorption of potash so that an accumulation of iron and aluminum compounds in the nodal tissue did not take place. The results indicate the importance of potash in the control of root rots, although this probably does not depend upon any one factor but upon the complex relation of essential nutrients in the soil solution. A definite relation was found to exist between the nodal tissue discolorations and the disintegration and the absorption of iron and aluminum compounds from the soil.

In studies of corn root rot at the Kansas station, the following organisms were found in the order of their prevalence: *Fusarium moniliforme*, *Diplodia* sp., and *Gibberella saubinetii*, the second and third being the common cause of wheat scab in Indiana and Illinois. *F. moniliforme* was present in 80 per cent of the samples examined.

The Maryland station found that seed selection for root rot reduced general infection 7 per cent, and the severest infection 40 per cent.

A survey of seed corn in the State made by the Missouri station showed a high percentage of infection. In the order of their prevalence, the associated organisms were *F. moniliforme*, an organism closely resembling that variously described as *Cephalosporium sacchari*, *Diplodia zeæ*, and *G. saubinetii*. The amount of root and stalk rot in the field was correlated with the amount of infection in the seed. Seed disinfection reduced this to a considerable extent.

The Nebraska station found that root rot is quite definitely associated with type of ear, the smooth flinty type having the least rots.

The New Jersey stations isolated four organisms associated with this disease, two of which gave positive results under inoculation.

The Ohio station found that while root rot was usually caused by *Diplodia zeæ*, it sometimes resulted from the interaction of various organisms. Its damage may be greatly reduced by the use of the rag-doll germination test.

Studies at the Iowa station showed that infection with the dry rot of corn takes place at the top of the ear and at the nodes of the stalk. The fungus does not migrate up from the roots but lodges at the base

of the leaves and feeds on the old pollen collected at these places, later attacking the shanks and butts of ears. The fungus lives over winter in the spore stage on old stubble. Practically no injury was manifest on rapidly growing corn, attack being delayed until after flowering, the greatest damage being done after growth stopped. Hot, wet weather at the time of denting was most favorable to the spread of the fungus. The injury to the seed is of great importance, many small kernels being killed outright, and in others the viability is so lowered that they produce weak plants.

The Tennessee station found *G. saubinetii*, the wheat scab fungus, to be seldom associated with corn seed, although it is common on dead cornstalks. The seed is not infrequently infected with the Fusaria of the elegans type, but most commonly, both externally and internally, with Fusaria of the moniliforme type, although these are by no means all of the same species, differing from each other in several morphologically important characters, thus representing several distinct organisms. Seed heated with hot water at 129° F. for 10 to 20 minutes was not affected either as to germination or fusarial contamination. When, however, the temperature was raised to 131° F. and higher, the fusarial contamination was greatly reduced, although the highest temperature tried, 139° F, did not completely free the seed from contamination. Germination was retarded by temperatures of 134° F. and up. Presoaking the seed in hot water (125°–130° F.) for a period of 24 hours was partially effective against fusarial contamination. Longer soakings were less effective. Corrosive sublimate treatment was very effective against surface contamination, but entirely ineffective against internal contamination. The treatment greatly reduced decaying of the primary root system of corn seedlings when the treated seed was planted in unsterilized, rich garden soil. The combined hot water and corrosive sublimate treatment was very effective.

The Delaware station found that, of the various organisms concerned in the more common corn diseases, *G. saubinetii* was most active in reducing yields, in causing root rot, and in crippling seedling roots.

Cotton diseases.—The Arkansas station reported a new blight of cotton caused by *Ascochyta gossypii*, which attacks all aboveground parts of the plant and may completely kill it. It also causes a severe boll rot. The fungus lives over winter on dead stalks in the field and infects the new crop the following spring. Rotation of crops is suggested as a remedy, but a one-year rotation was found to be insufficient to eradicate it. This station also found a wide difference in virulence in different strains of the fungus causing cotton wilt. Some wilt-resistant varieties lost their resistance in some localities. The organism is carried inside the seed, and therefore ordinary seed treatment is ineffective.

At the Arizona station it was found that cotton grown on alkali land was apparently not subject to black arm, perhaps because such plants are less succulent, the disease developing best on succulent plants.

Potato diseases.—Investigations at the Idaho station showed that calico disease of the potato is apparently transmitted not only by means of diseased tubers but also by spreading from plant to plant in the field.

Studies at the Nebraska station indicated that the leading factors in the spread of blackleg of potatoes are relatively high humidity with an optimum temperature of about 77° F. The organism remained viable with 100 per cent humidity at 77° F. At the same temperature with 90 per cent humidity, it remained viable only three hours, and at 80 per cent or less only two hours. Low temperatures and low humidity in ordinary storage cellars appeared to effectively control the disease.

At the North Dakota station it was found that a large percentage of the discoloration of the potato tubers is due to blackleg bacteria. Thirty-five per cent of discolored stem ends were infected with *Fusarium oxysporium* and 18 per cent with *Bacillus phytophthorus*, 24 per cent failing to show any fungus growth. Six per cent of the tubers were infected with both the Fusarium of wilt and the blackleg organisms.

In cage tests at the Idaho station of insect transmission of potato mosaic and leaf roll, positive results were secured only with the pink and green rose aphis (*Macrosporium solanifolii*).

In studies on Rhizoctonia at the Washington station midseason plantings (about May 20) gave the largest total yield and also the largest yield of marketable stock. Late plantings (July 1) gave the largest percentage of clean tubers. Plantings after June 1 showed a steady increase in percentage of clean tubers over earlier plantings. Seed treated with corrosive sublimate produced a higher percentage of clean tubers than untreated seed. Experiments at the Idaho station on the influence of successive dipping of seed potatoes upon the strength of corrosive sublimate solution showed that when clean, whole potatoes were treated the strength of the solution could be kept of normal strength by adding one-fourth ounce of corrosive sublimate for every 2 bushels of potatoes treated. Cut or dirty potatoes broke down the solution very rapidly, and if treated in sacks these also reduced the strength of the solution.

Experiments at the New Jersey stations showed that where potato scab had prevailed in the field the previous year, the use of from 400 to 600 pounds of sulphur on heavy soils and from 300 to 400 pounds on light soils gave the best results in control of the disease. The use of sulphur is not recommended where only a little scab has prevailed since green manures and fertilizers will make the soil sufficiently acid.

Studies at the Oregon station indicated the necessity of rotation of crops and the value of field roguing in the control of potato wilt. The disease was found to spread from plant to plant under ground during the growing season, suggesting that not only should plants be removed as soon as they show signs of wilt, but that it is safer also to remove the next plants in the row on each side.

The Nebraska station found little evidence that *Fusarium oxysporium* causes much wilt and rot of potatoes in Nebraska. *F. martii* causes a large amount of wilt. Experiments showed that infection occurs more commonly from the soil than from the seed. Discoloration of the tuber is not an absolute criterion of the presence of the fungus. The Delaware station found that *F. eumartii* causes a trouble similar to *F. oxysporium*. Positive evidence of the overwintering of *F. oxysporium* in the soil was secured, but healthy tubers planted in soil developed infection.

The Maine station continued its extensive studies on degeneration diseases of the potato, including mild mosaic, crinkle mosaic, rugose mosaic, leaf roll, streak, spindle tuber, and curly dwarf. Transmission by aphids was demonstrated for all except streak, by leaf mutilation inoculation for all except leaf roll, and by grafting for spindle tuber disease and others except leaf roll. Spread in the field by natural means was greater the larger the number of aphids present. Tests of means of control of these diseases showed roguing to be incompletely effective and fertilizer treatment to be useless. Bin and hill selection are only partly effective. Insect elimination was difficult to secure over large areas. Selection and isolation of healthy strains were effective. The "running out" of potatoes was found to be traceable to a number of diseases varying with variety and climate as to symptoms, percentage of infection, and rapidity of spread; otherwise there appears to be no such thing as "running out." Uniformly strong stock planted in isolated fields (at least 300 feet from previously planted fields) and the removal of all weak hills before plant lice appear reduced degeneration, while the omission of these precautions resulted in degeneration.

Tobacco disease.—Experiments at the Wisconsin station showed that the organism of the black root rot of tobacco can persist in the ground at least six years even in the absence of the tobacco plant as a host, but gradually decreases in virulence. The Kentucky station found soil infection with *Thielavia basicola* to be widespread, persistent, and difficult to control. Some especially desirable strains of White Burley tobacco resistant to the root rot have been developed. Soil sterilization did not give entire satisfaction at the Georgia station as a means of controlling root rot. The Wisconsin station has had several strains that seem to have marked resistance to the disease The Connecticut State station secured the asco stage of one strain of tobacco Thielavia from the violet and also found it on sweet and garden peas.

Studies on tobacco wildfire at the Connecticut State station showed that the disease can carry over on unsweated tobacco leaves, but is not carried over in the field to any extent. Driving rains help to spread the disease. The seed is not thought to be much of a factor in transmission. There does not seem to be much hope of securing immunity. Broadleaf tobacco suffers especially from the disease on account of its habit of growth. It is not bad on Cuban tobacco grown under cover. The station has developed promising methods of control. At the Massachusetts station it was found that success in controlling wildfire does not always result from sterilizing the seed bed with corrosive sublimate. The organism will live over on tobacco leaves, suggesting that it might be spread by the dust from such leaves. No evidence was found that insects spread the disease. Studies at the Virginia station of the control of angular leaf spot (blackfire) and wildfire showed seed selection and disinfection and plant bed and field sanitation to be practical measures which greatly reduce losses.

Other field crop diseases.—The Utah station studied what appeared to be an undescribed root rot of the sugar beet which appears to be especially favored by insufficient irrigation and is characterized by a fungus attack on the beet below the soil line, working upward in the

tissues and eventually destroying the crown. Examination of the leaves showed what appeared to be typical mycelia of the sterile or Rhizoctonia stage of *Corticum vagum*. The disease was reproduced by inoculation experiments into healthy beets.

Investigations at the Louisiana station indicated the possibility of selecting strains of sugar cane more or less immune or tolerant to mosaic, and the Porto Rico station found that the introduction of immune varieties furnishes an effective means of control of this menace to the sugar industry.

Studies at the Montana station indicated that sunflower wilt is probably due to a species of Sclerotinia. Seven strains have been isolated that are culturally identical or nearly so. The disease usually makes its appearance when the plants are 4 to 6 feet high, attacking roots and crowns, and the plants wilt and die. Losses range from 10 to 60 per cent of the sunflowers in the field. The fungus appears to spread through the ground rapidly. In one instance it was found to attack a patch of Canada thistles, and there is some evidence that wild and cultivated lettuce are possible hosts. The organism was found wintering over on all sunflower stalks. The perfect stage was not found. It is believed that a rotation of sunflowers with grasses and grains would lessen the loss. A downy mildew of sunflowers caused by *Peronospora halstedii* was also found.

Tomato diseases.—Studies on tomato blight at the Maryland station showed that the organism (*Septoria lycopersici*) lives over winter in the dead stems of the tomato and also on the horse nettle, Jimson weed, and potato. The perfect stage was not found. Considerable success was attained in developing an early resistant tomato. At the Washington station some evidence was obtained indicating that the disease may be due to the joint attack of a Rhizoctonia and a Fusarium. The Rhizoctonia on the tomato was found to be the same species as that occurring on the potato. The New Mexico station found that the disease can be materially reduced if medium to heavy soils are used instead of light soils.

Examination at the Washington station of a large number of apparently healthy plants showed a very large percentage of these to have mycelium of Rhizoctonia in abundance and over 50 per cent to have sclerotial development on the roots, proving that the tomato may be infected with this fungus and not display symptoms of blight.

In a study of tomato mosaic at the Indiana station much evidence was obtained of the overwintering of the disease on the horse nettle and certain ground cherries. Eradicating these weeds from plant beds and fields resulted in a marked control of the disease.

The Arkansas station found tomato wilt to be a seed-borne disease, probably both inside and outside of the seed. Some progress was made in developing wilt-resistant varieties.

The West Virginia station reported a new disease of tomatoes, a rot apparently due to Pythiacystis, which also causes the brown rot of lemons.

Other vegetable diseases.—At the New Hampshire station dusting with Bordeaux mixture gave satisfactory control of bean anthracnose, especially if sugar was added, which reduced the amount of scorching. This treatment reduced the disease to 0.3 per cent.

Studies of an apparently unrecorded disease of Lima beans at the Virginia station, attacking the beans in the pod to a serious extent in some sections, showed the causal organism to be a yeast, a species of Nematospora.

The Massachusetts station isolated a species of Macrosporium from carrot blight that gave 100 per cent infection by inoculation. The disease affects the seed-bed plants, as well as those in the field. Bordeaux mixture gave fair control, depending upon weather conditions.

The Michigan station found celery yellows to be seed-borne, some varieties being resistant to it.

Cucumber mosaic was found by the Wisconsin station to be carried over winter on the pokeweed, milkweed, and wild cucumber, and was transmitted to pigweed and the cultivated ground cherry.

The New Jersey stations found that seeds from fruit affected with eggplant wilt were free from it. Infection may occur in the seed bed, transplant bed, or field.

The Arizona station isolated a bacterium from the bacterial rot of lettuce that will produce the rot when inoculated into healthy plants. The Kansas station found that a Botrytis disease causing flower and foliage rot of greenhouse geraniums produced a gray mold on lettuce, causing a slimy rot. The Kentucky station found that the organism causing root rot and tipburn of lettuce is seed-borne and may be prevalent in garden soils and refuse, but apparently is not present in virgin soils.

At the Oregon station excellent protection from onion smut was secured by the use of formaldehyde, 1 ounce to 1 gallon of water, in a stream of not less than five-sixteenths of an inch in diameter, run into the furrow as the seed was dropped.

The New Jersey stations isolated an organism from peas affected with root rot that reproduced the disease by inoculation. Studies at the Utah station showed Pythium (probably *P. debaryanum*) to be the primary cause of root rot associated with Rhizoctonia and Fusaria.

The Georgia station found the fruit rot of peppers to be a bacterial spot disease. It was successfully transferred from peppers to tomatoes and back again. In studies on pepper mosaic it was found that aphids become a factor in the spread of the disease after it has started in the seed bed and in the field, but do not carry over the infection from one season to another. The spores of pepper leaf spot disease were found to be carried from one season to the next on the surface of seeds. In studies on the Sclerotium wilt of peppers at the Louisiana station about 5 per cent of potato plants were found to be infected with the disease, although only usually about 1 or 2 per cent are attacked. It occurs also on beans and has a wide range of hosts. The New Mexico station found that excessive heat and a high percentage of soil moisture are factors which help to develop disease in the Chili pepper.

Apple diseases.—For the control of apple anthracnose the Oregon station got the best results by the use of Bordeaux in one of the late codling moth sprays.

The Virginia station found apple black root rot to be largely due to *Xylaria digitata*, but *X. polymorpha* is also sometimes concerned, climatic conditions determining the prevalent species.

Studies at the Indiana station of the cankers produced by apple blotch showed that about 95 per cent occurred at leaf scars and was the result of leaf petiole infection and subsequent invasion of the twig through the petiole. Bordeaux mixture prevented petiole as well as fruit infection.

The Missouri station found that in most cases cleaning and sterilizing apple canker with bichlorid of mercury, mercuric cyanid, and other applications were ineffective.

Studies on apple rosette at the Washington station showed this to be a physiological trouble found only in alkali soil districts and practically always disappearing within three years after an orchard is planted to a legume cover crop. Chemical analysis showed the rosette twigs to have a much higher ash and nitrogen content than normal twigs.

Tests of means of control of apple scab at the Indiana station showed liquid lime sulphur to be more effective than dust and dusting to be more expensive than spraying. At the New Hampshire station Bordeaux mixture, copper acetate, or lime sulphur gave satisfactory control. Copper acetate was used at the rate of 2 pounds to 50 gallons of water, with 10 pounds of lime. Adding sugar to the mixture increased the injury to the foliage, especially when the amount of lime was high. The best control was secured by using sprays in the prepink stage. At the Montana station lime sulphur was succesfully used instead of Bordeaux in the control of this disease, the latter causing injury to the fruit.

Studies on frog-eye of apple leaves at the West Virginia station indicated that there are several fungi capable of causing this disease.

Peach diseases.—Studies at the Maryland station showed that Sclerotinia fruit rot of peaches is carried over winter both in mummied peaches and twig cankers.

Investigations on peach yellows at the Delaware station resulted in failure in all attempts to produce the disease by inoculation of healthy trees with diseased sap or emulsions of materials from infected trees. The pollen from infected trees was found to be weak and not able to pollinate healthy flowers. Premature fruit was the earliest evidence of yellows. June drop was not found to be due to faulty pollination or fertilization of the cell. Fully developed embryos were found in all specimens of dropped fruit.

At the Georgia station cross inoculations of peach rosette were made from the peach to the plum, peach to apricot, apricot to peach, peach to Mazzard cherry, almond to peach, and other combinations. The Marianna plum is apparently immune to the disease.

Citrus diseases.—At the California station citrus blast was found to be caused by the same organism that causes citrus black pit. It is spread by winds and gains entrance through slight injuries in the tree. Trees protected from the wind were not so much affected. Methods of control were perfected.

The Florida station found that the fungus *Phomopsis citri* grew best on a medium of 2 per cent solution of starch as a carbohydrate and filter paper as a source of cellulose. It did not grow in cultures to which a few drops of oil of orange had been added. In inoculation experiments the fungus produced melanose only on young tissue, leaves 2 or 3 weeks old being very susceptible; but those 4 to 8 weeks

old were very difficult to infect. Similarly, after the fruit had reached a certain stage, it was no longer subject to melanose spotting. The inoculation period ranged from four to seven days, generally five, and young fruits inocluated with the disease showed infection in four or five days. Early spraying with a 3–3–50 Bordeaux mixture, with the addition of 1 gallon of oil emulsion to 50 gallons of spray, gave excellent control. This station also studied stem end rot of citrus, and found that where this disease was present the abcission layer in the fruit had already formed and that apparently a fruit can not be infected with the disease until the abcission layer is formed.

Studies on the internal decline of lemons at the California station showed that prevention of the trouble lies in a uniform and liberal supply of water during periods of severe, hot, dry weather.

Other fruit diseases.—In studies at the Colorado station of a bacterial disease of the Wragg cherry, spots on the leaves similar to those occurring on naturally infected trees were produced by spraying with cultures of *Pseudomonas pruni*. It appeared to carry over in the twigs and apparently had some connection with hail injury, varying much in different seasons. The plum and peach were also found to be susceptible. At the South Carolina station, good results were obtained in the control of cherry leaf spot on eight varieties of sour cherries by spraying with Bordeaux mixture 2½–6–50, the first spray immediatly after the leaves had fallen, the second three weeks later, and the third directly after picking the fruit.

Studies at the Georgia station indicated that several species of Glœosporium and Colletotrichum may cause fruit rots. One form was found that attacks green fruit and also infects the leaves. One organism was found on the cotyledons of seedlings, indicating that it may be seed-borne, and some of the organisms were found to live on leaves of the plants until fruit was set. Inoculations of seed with spores from a phoma rot resulted in infected seedlings. The Maryland station isolated a number of strains of the brown rot fungus, which differ morphologically but not in virulence. They were found to develop the apothecial stage only when near the surface. Their development took place to a considerable extent during the first year, but in the greenhouse it sometimes required only a few weeks. The disease attacks nearly all fruits and the mode of entrance is mainly through wounds made by insects.

Mosaic.—Investigations at the Iowa station showed that mosaic of certain species of Cucurbitaceæ, Leguminosæ, Solanaceæ, and Labiatæ are interchangeable. Mosaic of tobacco, potatoes, and tomatoes can cross over to cucumbers, beans, and other crops. Many wild perennial plants, as wild ground cherries, milkweeds, and smartweeds, may serve as sources of spring infection in the above crops. Aphids, the striped cucumber beetle, and mealybugs act as carriers of the infective principle in the greenhouse. The Wisconsin station found that, although relatively high temperatures are most favorable for tobacco mosaic, relatively low temperatures (57° to 65° F.) are most favorable for the development of the disease on the potato. Above 77° the symptoms of the disease disappeared rapidly.

Texas root rot.—The Texas station found that the causal organism of Texas root rot is carried through the winter on susceptible living host plants, including cotton, tie vine, okra, pepper, castor bean, and many other plants, the roots of which remain alive during the winter

even after the tops are killed back by frost. The fruiting stage (*Phymatotrichum omnivorum*) of the root rot fungus was secured in cultures but was found to be very rare in the field. This is a summer stage only, and the spores will not germinate. Artificial inoculations with this fungus reproduced the disease on cotton. A large number of susceptible plants were found, including fruits, berries, truck and field crops, and ornamentals.

Chlorosis.—In experiments at the Delaware station with wheat, corn, and soy beans chlorosis due to insolubility of iron occurred with all concentrations over pH 6. At the New York Cornell station chlorosis was found to be due in part to accumulation of sugars.

Other diseases.—Studies at Utah station showed a soil temperature of 18° C. to be most favorable for the pathogenic action of *Corticium vagum*, which closely approximates the optimum temperature for the general development of its host, the potato.

Studies on the European canker at the Oregon station showed that the Fusarium stage of the fungus appeared in the fall after the rains set in, and the Ascochyta stage appeared in December, the spores being shed from that time until spring. Infections were obtained by inoculating broken tissues of Anjou pears with cultures of the fungus, best inoculations being obtained in January. Natural infection was brought about usually through pruning wounds or leaf scars. Spraying in the autumn with Boadeaux mixture controlled the disease.

Response to environment.—Studies at the Wisconsin station on the susceptibility of wheat and corn to the wheat scab organism showed that wheat seedlings blight in a comparatively warm soil, and corn blights in cool soil. The response to soil moisture, irrespective of the temperature, was the same, dry soils being most favorable. The composition of the wheat and corn seedlings evidently had some bearing on this, for it was found that wheat seedlings in a low soil temperature and corn seedlings in a high soil temperature were both characterized by being high in available carbohydrates and low in available nitrogen, and large amounts of available sugar were being rapidly converted into cellulose. The studies indicated that disease resistance and predisposition to resistance, in this case at least, may have been largely dependent upon the environmental conditions under which the plant was grown.

Fungicides.—At the New Hampshire station sulphur was found to be toxic only when in the presence of oxygen, and was more active at high than at low temperatures. Sulphids were extremely toxic, but the polysulphids decomposed rapidly on drying and their value was merely a contactual one.

ENTOMOLOGY

Orchard fruit insects.—Studies of the green aphis on apples at the West Virginia station indicated that it is not safe to take the activity of the tree as an index to the condition of the aphis eggs and as a basis for establishing dates for treatment. The Idaho station reports good control of the apple leaf roller with two sprayings, one when the trees were in a full pink stage and a second, calyx spray. Arsenate of lead, 12 pounds to 200 gallons of water, or Paris green, 6 pounds to 200 gallons, with lime added to prevent burning, gave good re-

sults. At the Pennsylvania station, late summer sprays of arsenate of lead, toward the end of July or the first of August, proved very successful in controlling the late-feeding generations of the leaf roller. Good control of the apple flea beetle was secured at the Ohio station by winter plowing and cultivation. The Oregon station secured best control of the apple blister mite with an oil emulsion consisting of 2 gallons of oil in 100 gallons of lime sulphur.

At the Maryland station tests with an emulsion of paradichlorbenzene in creosote proved effective in control of the peach borer and did not injure trees on drained land. The Michigan station found an effective repellent for the borer to be a mixture of soap, naphthol, flour, and sugar cooked together. Details of the treatment with paradichlorbenzene were studied at the New Jersey stations. On wet soil the effect was greatly interfered with. Temperature was also a factor. In a dry soil, at a temperature of 60° F., 4 inches below the surface, three weeks were required to get the full effect: while at 70° only two weeks were required. Fall treatment proved preferable. The North Carolina station showed that by clearing up around the orchards, applying four sprays during the season, and picking up all the dropped fruit, peach curculio injury could be reduced to a negligible quantity.

The Oregon station found that the pear leaf blister mite also attacks the apple and appears to injure the mountain ash. A combination of lime-sulphur, 1–12, plus oil emulsion, 2–100, was highly efficient, and early applications for its control on the apple are recommended.

Studies at the California station showed that the same species of codling moth attacks both the apple and the walnut and shows no choice of food plant. Spraying with lead arsenate showed a higher efficiency at less cost than dusting, one application in June being sufficient for walnuts. The Colorado station found that the average time of development of the codling moth, from egg to egg, varied from about 50 to 60 days. The most efficient control was secured by spraying with arsenate of lead, three to five applications being necessary. Picking and destroying all wormy apples is recommended. At the Idaho station it was found that 73.3 per cent of the spring brood transforms to moths, the remaining 26.7 per cent entering hibernation. The New Jersey stations report that it is necessary to keep apples coated with poison in order to control the moth. The New Mexico station found four broods a year in that State, the fourth brood overwintering. The largest deposits of eggs were found in July and August. With six sprayings, from 80 to 90 per cent of sound fruit was obtained. One and one-half pounds of arsenate of lead to 50 gallons of water is recommended, the first spray being given during the last of April or the first of May, or when 90 to 100 per cent of the petals have fallen, the second 15 days later and repeated after 46 days and 66 days, respectively, thereafter. Most of the invasion was observed to be through the sides of the fruit. At the Oregon station dusting generally gave control comparable with that of liquid sprays. The addition of spreaders improved the control. The Washington station reports that lead arsenate proved to be better than calcium or magnesium arsenates. The addition of a spreader at this station did not appear to increase the efficiency.

Studies of tent caterpillars at the Oregon station showed the percentage of parasitism to vary from 30 to 90 per cent, the major parasite being an undetermined Tachinid fly.

The Arizona station reports successful control of the date scale by burning over the trees with a torch after defoliating them, the trees recovering from the treatment in about three years.

Small fruit insects.—At the Washington station it was found that almost complete extermination of the cranberry fireworm may be secured, without serious injury to the plant, by spraying the eggs with a miscible oil. Fumigation under cover with carbon disulphid for the larger vine weevil on cranberries was not successful. At the New Jersey stations the cranberry girdler was controlled by three days' flooding in August, less damage resulting to the plants from shallow flooding.

The Kentucky station found that there are apparently various forms of the grape leaf hopper, one feeding on the sycamore as well as on the grape.

Studies at the Wisconsin station showed that the raspberry cane borer, which is doing considerable injury to the crop in the State, can be held in check by carefully pruning the canes below the gall caused by the borer and burning the cuttings.

The Tennessee station reports that the strawberry weevil does very serious injury in parts of that State. Contrary to observations farther north, the insect winters over in the woods, and there is a much larger number of host plants. New beds and those in the vicinity of woods are most often injured. The weevil was found to cut and to breed in the buds of the apple, a hitherto unreported host plant. The newly emerged adults were also found to injure buds of tomato and cotton. Studies on the strawberry crown borer at the same station showed that this insect has become so numerous in the State as to seriously interfere with the production of runners. It was found to feed upon the blackberry and was bred experimentally upon *Duchesnea indica* and *Potentilla primula*. Old and abandoned strawberry patches appeared to be the chief source of infestation, the life cycle being ordinarily one year. Egg laying begins in March, the egg stage lasting 18 days, the larval stage 39 days, and the pupal stage 11½ days. The insect is unable to emerge when buried 3 to 6 inches deep in moist, compacted soil.

In studies at this station on the strawberry root louse it was found that egg laying begins about the middle of November and lasts until January 1. The first eggs hatched in the field the middle of February and continued from then until November. Reproduction was observed to be parthenogenetic. Plants that were kept heavily infested during the summer produced as many runners as uninfested, sprayed plants. This may be explained by the presence of parasites which appeared as soon as the lice became at all abundant, especially a fly, *Paragus bicolor*, which has not previously been recorded as an enemy to the strawberry root louse. Two new parasites were found, a syrphid fly (*P. angustifrons*) and a small wasp (*Diaretus fuscicornis*). A new ant (*Pherdole vinlandica*) was found to attend and protect the lice, but it was not found so often on the roots as on the crown and leaves.

Pecan insects.—At the Mississippi station May beetles belonging to the genus Phyllophaga were found to cause serious injury to pecans.

Of the 42 species occurring in the State, 22 were found feeding on the pecan. The Texas station controlled the pecan case-bearer or bud moth by spraying with arsenate of lead, 3 pounds to 50 gallons of water.

Insects of ornamentals.—At the Maryland station molasses and nicotin sulphate proved quite effective in controlling the boxwood leaf miner and did not injure the foliage. It was necessary to repeat two or three times and after rains. The station also found that the chrysanthemum midge may be controlled with a spray of nicotin sulphate and soap, applied every fourth day during the egg stage, followed by semiweekly spraying during the adult stage. There were found to be four broods in the spring and three in the fall. The midge was found to live over winter out of doors in old plants, which should therefore be destroyed.

Field crop insects.—The Texas station found that the alfalfa weevil can be controlled by grazing the fields with sheep in the late fall. The Idaho station reports that a parasite (*Bathyplectes curculionis*), introduced in 1921, has become established and seems to be assisting materially in controlling the insect.

At the New York Cornell station it was found that the clover seed midge, which has two broods a year, can be largely controlled in the second brood by cutting the first crop early so that this brood has no green material to feed on.

The Virginia station controlled the larger cornstalk borer by plowing the corn stubble in December, harrowing immediately, and leaving the soil undisturbed until the following March. The Oklahoma station found the corn plant louse (*Aphis maidis*) on the dock. It differed on different host plants, a considerable list of which was noted, including practically all of the cereals.

A method of boll-weevil control based upon removal and destruction of all squares at time of emergence of the weevils, followed at once by thorough application of calcium arsenate or lead arsenate, was evolved and tested by the Florida station with results indicating that the method will insure at least 90 per cent of a normal crop at a cost for treatment of less than $2 per acre. The South Carolina station showed that the hand duster can be satisfactorily used on small farms to control the cotton boll weevil. The effectiveness of calcium arsenate dusting varied in different localities, depending upon the amount of infestation, quality of the land, climatic conditions, and other factors, but in general it was profitable in all sections of the State. Two parasites were reared at the North Carolina station, one being common and killing about 13 per cent of the weevils in the field.

The Arizona station found that the moth of the Thurberia cotton bollworm occurs on wild cotton but will not deposit eggs on tame cotton. The native boll weevil infests tame cotton but the bollworm does not, although the larvæ of the latter will live and develop on tame cotton. Life history studies of the bollworm indicated five instars, with 6 or 7 days for the egg stage, 1 month for the larval stage, and 10 months for the pupal stage.

The Oklahoma station found that the cowpea louse is the same as the melon and cotton louse, and that it has 40 to 50 other host plants, It occurs on citrus, and an oviparous form is found on the straw-

berry, but the eggs are sterile. These are all forms of *Aphis rumicis*. but vary so widely for each kind of plant that different descriptions are necessary. Spraying with hydrate of lime with 5 per cent nicotin sulphate gave good control.

The Iowa station showed that there is considerable varietal difference in susceptibility to the potato leaf hopper and hopperburn, Rural New Yorker and Early Ohio being quite resistant, while Bliss Triumph and Irish Cobbler are more susceptible. The disease was largly controlled in northern Iowa by planting a resistant variety comparatively late in order to escape the spring flight of the hoppers, and spraying at least three times with a 4–6–50 Bordeaux mixture. Determining factors in immunity appeared to be succulence and the rate and period of growth, the high degree of immunity of Rural New Yorker being due apparently to the fact that it is not especially succulent, has a rather tough skin, and is slow growing and has a long growth period. Date of planting also exerted a decisive influence, late plantings (June 14) showing no hopperburn, whereas the earlier plantings succumbed. Dusting three times with copper arsenate failed to give satisfactory control. The New Jersey stations found that although dusting will repel the potato flea beetle, an emulsion of carbon disulphid and fish-oil soap promises to be a killing mixture. Tests at the Wisconsin station showed nicotin dust to be 100 per cent efficient against the flea beetle.

The Kansas station found chinch bugs hibernating on Sudan grass. *Aphis maidis* was found to attack sorghum as well as corn and to affect the germination of the seed. Hybrids of milo and sorghum were found to be resistant to chinch bug injury.

Studies on the sugar-beet louse by the Utah station showed that by May 15 the maggots had worked to the surface and pupated, the flies beginning to come out by June 1 and to oviposit on the underside of the leaves, producing full-grown maggots by July 1. There was only one brood a year. Many weeds were found to be host plants. It was also found that the insect withstands much dryness as well as moisture.

The California station secured evidence indicating that curly leaf of sugar beets is not produced by a toxin injected into the beet by the leaf hopper. The incubation period in the beet was found to depend upon the size of the beet. It was not possible to reduce the incubation period in the hopper to less than four hours. The minimum incubation period of the infective principle in the leaf hopper was four hours at a mean temperature of 100° F. and in the sugar beet three days at a mean temperature of 80.3°. The leaf hopper was not infective when it hatched. Some of the nymphs molted six times under high temperature and five times under low. It was not demonstrated that the hopper was a mechanical carrier of the disease.

Leaf hoppers which had fasted and whose mouth parts were contaminated with *Bacillus morulans* isolated from diseased beets, when allowed to puncture a healthy leaf failed to transmit the disease as did those which were allowed to inject into the tissues bacteria rubbed on a portion of the beet leaf. Daily inoculations of juice from beets upon which the hoppers had fed for from one to eight days, or until the earliest symptoms of curly leaf appeared, failed to produce the disease in healthy beets; and juice exuding from diseased beets in the field gave negative results when inoculated into healthy beets.

The excrement when injected into the petioles of healthy beets did not produce the disease. It was not transmitted through the seeds from stechling beets affected with the disease before and after transplanting.

The hoppers overwintered on Alfilaria and Atriplex and also bred on *Chenopodium morale*. Thirty-five host plants have been found to date. The hoppers did not breed where the climate was moist. Five broods were recorded in the San Joaquin Valley and only two in Salinas Valley, where there is more fog. Dusting with a mixture of kaolin, lime, and 10 per cent of Black Leaf 40 showed a large reduction in the number of hoppers. It was most effective when applied shortly after the spring invasion of the beet fields by adults. Three egg parasites were found.

The Montana station found about a dozen species of insects attacking the native sunflower that readily go to the cultivated plant and cause considerable damage. The Colorado station found that the sunflower aphis winters on the dogwood, and is best controlled by spraying this host.

The Texas station observed flights of 100 yards by the sweet potato weevil in the field, and this must be considered as a means of dissemination. As control measures, clean culture, quarantine, prompt and proper harvesting, and rotation are recommended. Studies of the effectiveness of overflows and submergence for control showed that the adult weevil may remain alive, floating on the surface of water for 216 hours, and that the immature weevils are not easily affected by submergence.

Investigations at the South Dakota station showed that the wheat-stem maggot pupates within the leaf sheath of the wheat plant about an inch below the ligule. Infected plants may be recognized when mature by the white heads and spreading awns. Parasitic control seemed to be of some importance.

Insects affecting vegetables.—The Wisconsin station reports control of the striped cucumber beetle by two or three thorough applications of dust containing 10 per cent nicotin sulphate, the first application being made early in June. Flight tests showed that this insect seldom flies over half a mile. There are two generations of the beetle in Wisconsin and sometimes a partial third. In studies at the Arkansas station, migration of this insect occurred early in the spring, and after settling they did not move much. Powdered arsenate of lead, 2 pounds to 50 pounds of lime, mixed with a little molasses, was very effective in control.

The Florida station worked out the life history of the bean Jassid (*Empoasca mali*) for that State, and devised a new type of spraying machine, which is very successful in its control. Studies on the bean weevil at the New Jersey stations showed that ball clay is an effective protection when used in the proportion of 1 part of clay to 10 parts of beans. The same material successfully protected corn against the grain moth when used at the rate of 1 part of clay to 50 parts of corn. At the Colorado station, the Mexican bean beetle was found to winter as an adult and to come out of hibernation the middle or latter part of June. There was one main life cycle, but a few passed through a second cycle. The maximum injury was observed in the latter part of July and during August. The most satisfactory control tested was spraying with arsenate of zinc (1 pound to 50 gallons

of water) or arsenate of lead (1 pound to 40 gallons), care being taken to apply the spray to the under surface of the leaf. One, two, or three sprayings may be necessary and early planting is desirable.

At the Maryland station, dusting with 5 per cent of nicotin gave excellent control of the pea aphis, dusted fields giving almost double the yields of undusted. The Wisconsin station found that although the first, second, and third nymph stages of the squash bug were readily killed with nicotin dust, the fourth and fifth nymphs, eggs, and adults were quite resistant.

Aphids.—At the Kansas station studies of the wing development of *Aphis prunifolia* showed that if the mother is winged, the progeny are wingless, and vice versa; if the mother is starved, the progeny are winged.

The Texas station, studying the factors determining the production of wings on aphids, found that at a temperature of 65° F. aphids generated without winged forms. Chemical and food conditions also had an effect. The male melon louse was not found.

At the Maine station two species of aphids troublesome on currants and gooseberries were found to migrate to willow herbs, on which the summer generations were passed. The alternate host of the pink and green potato aphis, a carrier of potato mosaic, was found to be the rose; and it is believed that by the destruction of rosebushes in the vicinity of potato fields this disease can be largely controlled. Although other insects may transmit the disease, in Maine at least this aphis is apparently the most important one.

Bees.—Observations at the Iowa station showed that when white clover was abundant and the weather favorable, workers made an average of 13 trips daily, while on unfavorable days only about eight trips were made. The average time spent in the hive by a bee returning from gathering honey or pollen was three or four minutes. The maximum load of nectar was found to be 85 per cent of the bee's weight, with an average of about 50 per cent. Observations indicated that only about 20 per cent of the bees in the hive were actually engaged in gathering nectar and honey. The highest observed speed of bees in flight was 25 miles per hour, but the average was considerably below 20 miles.

A survey of honey plants at the Kansas station showed that alfalfa does not produce nectar below 1,000 feet altitude. At the Minnesota station, Carniolan bees swarmed more than the Italians in the same-sized hive. The brood area on June 1 was in the proportion of 13 to 16 in favor of the Carniolans.

The Wisconsin station found a solution of sodium hypochlorite highly efficient in disinfecting hives and equipment, as well as for treating foul brood, by feeding sirup to which it had been added.

In investigations on the poisoning of bees by arsenical sprays, the Washington station found soluble oils and nicotin sulphate effective repellents when added to sprays.

At the Wisconsin station it was found that wintering colonies maintained a fairly constant temperature around the outside of the cluster, ranging from 57° to 60° F., regardless of how cold the weather was. As the temperature went down, the bees developed a higher temperature within the cluster by muscular activity; but if the low temperature was maintained very long, the bees were unable to resist and eventually died.

Grasshoppers and crickets.—The South Dakota station observed that there is usually but one brood of crickets a year in that State, and that there are from 9 to 11 stages in the life cycle. Two forms of *Gryllus assimilis* were found, one that hibernates in the egg stage, this being the most common, and one in the nymph stage. The eggs hatch from late in May to the middle of June. The two principal methods of control worked out were destruction of the eggs through cultivation, disking, or plowing, and killing the crickets with poison baits consisting of 20 pounds of bran, 2 quarts of blackstrap molasses, 1 pound of white arsenic or Paris green, and 3½ gallons of water. The control measures were most effective during July. The adult forms appear early in August. About 50 per cent of the eggs collected were parasitized. The Montana station found that poison bran was most effective for grasshopper control when applied from 7 to 11 a. m. The Oregon station found the most attractive bait to be bran and old sawdust in equal parts, with molasses, salt, white arsenic, and amyl acetate. When sodium arsenate was substituted for white arsenic, the bait appeared less attractive but killed in about half the time. The Wisconsin station found that sawdust could be substituted for bran in the bait, reducing the cost about one-half without diminishing the efficiency.

Cutworms.—The pale western cutworm, according to the Montana station, caused an estimated loss of 200,000 acres of grain in that State, valued at $3,000,000, in 1919. Summer fallowed fields, cultivated early to kill the weeds and not cultivated after July 15, became crusted over and were surprisingly free from cutworms. Spring grain seeded on very early spring plowing was seldom injured. Irrigation gave practically complete control. The North Dakota station found this insect to lay eggs mostly in August in wheat fields where the ground was quite loose. No crop, with the possible exception of sweet clover, was exempt from injury by this insect; but little or no damage followed such crops as late millet, late flax, corn, or potatoes.

The most troublesome species of cutworm observed by the North Carolina station was *Feltra gladiaria*. These were found to be readily checked or killed during the pupating stage by the slightest disturbance, thus suggesting summer cultivation as a control measure.

Flies.—Two new species and one new genus of the parasitic flies, Tachinidæ, were reported by the Texas station, one of the new species being parasitic on the cricket and one on the snail. The size was found to be dependent upon the food supply, and the color varied in the same species in different localities. The size and arrangement of the bristles varied considerably.

Soil insects and nematodes.—In investigations at the Washington station of various soil fumigants placed under ground and examined a few days later, in no case did the insecticides show any long-range effects, dead insects being found only within a radius of a foot or so from the point of administration.

At the New Hampshire station tobacco dust lime mixture used dry killed 100 per cent of the eggs or of the emerging larvæ of root maggots. There was, however, very little repellent action, although adult flies were found not to lay eggs freely on or near plants freshly treated with the mixture, and such eggs as were laid in contact with the mixture did not hatch. Protection rapidly diminished, however, when rains intervened. It was most important to protect the plants

during the first two or three weeks after they were set out. The treatment was successsful with cabbages, radishes, turnips, and cauliflowers.

The Florida station obtained striking results in the control of nematodes by summer fallowing in connection with growing a crop of bush velvet beans, which are practically immune. In seed-bed treatment with sodium cyanid and ammonium sulphate, better results were obtained by covering the bed with a gas-proof material, of which "balloon cloth" proved the best, giving better killing not only of the nematodes but also of other soil insect pests and even of Bermuda grass.

Scale insects.—The Mississippi station reported the occurrence of 82 species of scale insects in the State, not including some undetermined species. Tests with the San José scale at the Arkansas station showed that the common practice of using lime-sulphur as a winter spray is not as good as a spring spray. The December and January spray gave an 80 per cent kill, while a March spray gave 100 per cent. Tests of dry lime-sulphur and a number of proprietary insecticides at the Missouri station indicated that, although it was impracticable to eradicate San José scale from infected peach trees, proper application of most of the materials gave good results. In experiments with the oyster shell scale at the Indiana station, good control was obtained even in heavy infestations by spraying with whale-oil or fish-oil soap, 1 pound to 5 gallons of water, with the addition of an ounce of 40 per cent nicotin sulphate.

Stored products insects.—Studies at the Kansas station showed that the yellow and dark meal worms (*Tenebrio molitor* and *T. obscurus*) have a life cycle of one year when fed on flour, but a longer cycle when they are fed on bran. The West Virginia station found that very few weevils, moths, grain beetles, and other stored products insects were able to withstand a constant temperature of 35° C. (95° F.), although they may withstand temperatures up to 50° C. for a short time. Continuous temperatures of 90° to 95° F. killed all insects tested, but if the temperature was lowered occasionally 10° to 20° their development was normal. The Ohio station found an efficient method of killing insects in stored cereals without lessening the germinating power of the seed to be the maintaining of a temperature of 130° to 140° F. for four days.

Miscellaneous insects.—Life-history studies of the cheese fly at the California station showed that from 36 to 48 hours are passed in the egg stage, 8 to 15 days as a larva, 7 to 12 days as a pupa, and from 4 to 7 days' preoviposition period. In tight cheese rooms, 10 ounces of sodium cyanid per 1,000 cubic feet with 24 hours' exposure at 65° F. or above killed the adult cheese fly, pupæ, and exposed larvæ, and also cheese mites. The fumigation should be repeated two or three times at two-week intervals. Cheese exposed to the fumigant showed no appreciable evidence of absorption of the fumigant after a few hours' aeration. The Oregon station secured highly efficient control of the European earwig through the use of a poisoned bran bait, with sodium fluorid as a toxic agent.

The European red mite was shown by the Maryland station to be the same as the citrus mite. It was found to be especially serious on apples, but also laid eggs on the peach, the leaves of infected trees

losing their green color. Summer spraying with miscible oils proved quite effective in its control.

A study of the larger plant bugs at the Florida station showed that the seasonal activities of their parasites were practically the same as those of the insects. Sunflowers were found to be somewhat effective as a trap crop. Spraying for control of thrips on citrus was most effective when done in the height of bloom. Spraying did little good unless weeds were cut in orchards during the winter. Oranges were more severely injured by the insect than was grapefruit. The addition of nicotin sulphate to Bordeaux lime-sulphur increased its efficiency for use on grapefruit trees at blooming time. Liem-nicotin-sulphate dust was effective only when put directly into the bloom.

The Florida station reported a successful method of growing the brown fungus parasite of the white fly in cultures in a medium prepared from grasshopper soup, hardened with gelatin. This fungus was found to be a more efficient parasite than the red fungus.

The Idaho station found eight species of the false wireworm (Eleodes) in eastern Idaho, only one (*E. hispilabus*) occurring abundantly. The eggs are laid mostly in June and have an average incubation period of 135 days. The larvæ were found doing serious damage to both spring and fall planted wheat, one count showing them to occur at the rate of 2,537,200 per acre. Indications are that they remain in the soil about one year before transforming into beetles. They were successfully controlled by use of a poison mash made of bran, Paris green, amyl acetate, and water, applied as the beetles emerged and before they began egg laying.

Insecticides.—The New Jersey stations found that crystalloid carriers evolve nicotin much more rapidly than colloidal carriers, especially if the crystalloid is a carbonate. Fifty pounds of 1.5 per cent nicotin dust evolving 40 per cent of gas in 48 hours killed 90 per cent of aphids by asphyxiation.

The Minnesota station showed that for the control of grain insects a mixture of 90 per cent carbon tetrachlorid and 10 per cent chloropicrin was more toxic than either one alone. In a comparison of Bordeaux and copper arsenate dust, the dust proved almost a failure in controlling leaf hoppers on potatoes, but was fairly efficient in controlling some orchard pests.

The Oregon station showed calcium caseinate to have many advantages as a spreader for spray solutions. Its addition to combination sprays of lead arsenate-lime sulphur materially delayed the reaction between the two materials and the formation of an undesirable sludge. Used in the late cover sprays on apples, it minimized the uneven coloring of the highly colored varieties of fruit by forming a smooth, even covering over them. It tended to increase the number of trees covered per tank of spray and there was no evidence that it adversely affected the toxicity of the arsenical spray.

The Pennsylvania station found that dusting was as efficient as liquid sprays for control of plant lice on rutabagas, and field tests showed the covering of the under sides of the leaves to be more uniform with the dust.

Slugs.—The gray garden slug was reported by the Oregon station as causing severe injury to fields of clover, rye, and oats. Two hundred mesh dehydrated copper sulphate dust and Bordeaux dust

killed every slug hit. Eight pounds of dust to the acre appeared to be sufficient. Copper carbonate dusts were not equally effective.

BEEF CATTLE

The age factor.—Tests at the Arizona station showed that it costs only about half as much to put on gain with calves as with older cows. At the Missouri station the younger cattle made somewhat more economical gains than the older and more mature cattle; but since they grew as well as fattened, they were not put in marketable condition as quickly as older cattle. At the Nebraska station more economical beef was produced by calves than by older cattle. Calves made as much gain of beef from 61 pounds of feed as 3-year-old animals made from 100 pounds. Young cattle made more constant gains over long feeding periods. Better-bred cattle made larger gains at less cost. The use of supplements did not prove economically profitable.

Changes in body composition.—The Missouri station found in general that the percentage of fatty tissue increased and of bone decreased with age and fatness. The composition of the carcass became fairly constant at 8 to 10 months of age. The total nitrogen did not materially change with the condition of the animal. The nitrogen increased with age at apparently three periods—3 months, 3 to 12 months, and 12 months to maturity. The proportion of soluble nitrogen of the lean flesh tended to increase as the animal matured. Starvation withdrew the soluble nitrogen from the flesh. The proportion of soluble phosphorus tended to increase as the animal grew thinner, and the soluble ash increased somewhat as the plane of nutrition was lowered and decreased with age and fatness of the animal. The increase made by mature animals was nearly all fat.

Planes of nutrition.—The Missouri station found that if a steer was stunted for two years and then fed it would attain normal growth; but if stunted for a longer period normal growth was not restored. Other things being equal, steers on a low-protein diet did about as well as those on a high one.

Baby beef.—In experiments at the Minnesota station purebred Hereford calves, grades, and common beef calves fed a standard ration of shelled corn, ground oats, linseed meal, and alfalfa hay gave satisfactory gains; but the addition of a full feed of corn silage kept them more regularly on feed, and they consumed less grain and fattened faster at a reduced cost. In a lot receiving barley as a substitute for shelled corn, the gains were more rapid in the early period of feeding, but slowed down toward the end of the period, showing a decreased gain at an increased cost. The market quality of the purebreds and high grades was about the same. The common calves, which were very thin at the beginning of the experiment, gained more rapidly and on less feed than the others, but they did not finish as smoothly and sold for less per 100 pounds than the purebred animals. As the purchase price of the common calves was about half that paid for the purebreds, they gave the greatest financial gains.

Winter feeding.—The Montana station showed that calves can be satisfactorily wintered and grown on hay or hay and sunflower silage. A mixture of alsike clover and timothy hay was slightly superior to alfalfa alone. Except in cases of hay shortage with high prices and

relatively cheap grain, it was impractical to feed even a light grain ration to grade calves that were to be turned on grass the following season. With a medium grain ration, the calves were fatter than necessary for grazing purposes and not fat enough for killing purposes. This station also showed that if cows were in good condition in the fall they could be fed on mixed straw as the sole ration for the winter and produce strong calves, but if they were thin in the fall they would not do this.

The Oregon station found that young growing steers should hold their own during the winter, but large gains during the winter feeding period are neither necessary nor desirable unless they can be made economically.

Alfalfa hay.—At the Arizona station a Hereford cow maintained her weight and condition on alfalfa hay alone for four years. The Idaho station found that cutting alfalfa hay effected a saving of nearly 30 per cent of the hay and 13 per cent of the barley required to produce 100 pounds of gain.

Silage.—At the North Dakota station corn silage was found to be distinctly superior to sunflower, millet, and oat straw and sweet clover silages, both with reference to gains and finish of the steers. The Oklahoma station found that sunflower silage combined with shelled corn, cottonseed meal, and alfalfa hay gave better results than corn, kafir, cane, and darso silages for making beef. Corn silage ranked a close second, and the corn silage lot outranked all others in returns when the pork produced by hogs following the steers was taken into consideration. Sunflower silage gave practically the same gains as corn silage in baby beef production. Steer feeding experiments at the Colorado station showed sunflower silage to be 75 to 81 per cent as effective as corn silage, but, on account of the higher yield, cheaper.

In comparative tests at the South Dakota station the average daily gain per head was largest with steers which received corn silage and smallest with those receiving sunflower silage. The daily gains were not increased by mixing the silages. At the Washington station when corn and sunflower silages were fed to cattle during a period of 90 days, on the basis of the same amount of dry matter, the gains from the two were practically the same, but the most profitable gains were secured from sunflower silage. In comparative tests at the Wisconsin station with 2-year-old steers, corn silage and sunflower silage gave practically the same gains. Hogs following the steers, however, returned a greater profit for the lot receiving corn silage. In six years' experiments at the Pennsylvania station, a combination of corn silage full fed, cottonseed meal 2.5 to 3 pounds, and a small quantity of corn stover without any corn gave the largest net profits. In experiments at the Idaho station 1,000 pounds of silage replaced about 449 pounds of alfalfa hay and 20 pounds of barley in a ration for cattle.

Corn as feed.—Results of a number of trials at the Indiana station favored the use of a full feed of corn in fattening 2-year-old steers. Least profit was obtained where a half ration of corn was fed. It was not profitable to add cottonseed meal to a ration of corn, clover hay, and corn silage if a ton of meal cost more than 100 bushels of corn. In a comparison of feeding broken ear and shelled corn at the

Kentucky station, it was found that the latter did not pay for the labor of shelling.

At the Minnesota station, ground barley equaled shelled corn, pound for pound, in producing gains in weight in fattening steers; but pigs following cattle fed corn made a considerable saving, while those following steers receiving ground barley made practically no saving.

Peanuts and beans.—At the Georgia station peanuts added to the ration showed no effect on the chemical composition of the beef. At the New Mexico station cull pinto beans, corn stover, and bean straw, with corn, gave good maintenance but small gains. If more than 4 pounds a day of the beans were fed, the animals scoured. The straw proved to be a good roughage, high in protein. It formed a very satisfactory feed for hogs and sheep, which did not scour. Tests at the South Carolina station showed that cattle fed velvet beans as the sole concentrate did not put on flesh rapidly but made economical gains.

SHEEP AND GOATS

Breeding.—The Idaho station found sex in sheep to be a matter of inheritance, as had previously been found to be the case with swine, horses, and cattle. In cross-breeding experiments at the Oklahoma station, the polled character of Shropshires was found to be dominant over the horns of Dorsets. The influence of the ram was found to be stronger than that of the ewe in determining fineness of fleece. At the Nevada station a comparison of lambs from range flocks using purebred or highbred bucks with those from flocks using scrub bucks showed a marked difference in growth in favor of the purebred bucks.

Shearing and docking.—The Texas station obtained a little more wool by shearing twice a year, but the fleece was less valuable than that sheared once a year. Tests at the Pennsylvania station showed that there was practically no difference in rate of gain whether the hot docking pincers or the emasculator was used, and that castration performed at the time of docking did not lessen the gains.

Feeding lambs.—The Nebraska station, comparing lambs fed on corn and alfalfa alone with those receiving supplements of silage, molasses, alfalfa meal, and linseed meal, found that the cheapest gain was made on corn and alfalfa alone. With a lot of lambs allowed to run in the cornfield for 90 days, as compared with the dry lot feeding of corn, alfalfa, and oil meal, the cheapest gains were made with the corn-fed lot. At the North Dakota station lambs turned in a cornfield with no other feed for 49 days made an average daily gain of 0.244 pound and required 9.7 pounds of corn per pound of gain. In a comparison at the Idaho station of corn, barley, wheat, and oats as grain supplements for lambs, corn proved a better feed than barley. Both wheat and oats showed less gains and poorer finish. Cut hay proved slightly better than uncut. Lambs receiving silage in addition to alfalfa hay made the best gain and finish. No advantage was found in withholding grain during the first 30 days of feeding. Experiments in fattening lambs at the Washington station showed that taking the hay from the first cutting of alfalfa as 100, the value of the second cutting was only 63, and of the third 85, while that of the first cutting of sweet clover, 24 to 30 inches high, was 123. A lot of lambs with which one-third of the concentrate (corn) was replaced with beet molasses made as good gains as those

receiving corn alone, but had a slightly lower finish. At the Texas station milo and kafir produced practically the same gains as ground shelled corn when fed in the same amounts. In a comparison at the Indiana station of linseed-oil meal and cottonseed meal fed in connection with leguminous hay and in limited amounts, cottonseed meal was superior to linseed-oil meal for fattening lambs; but, when fed in liberal amounts not in connection with legume hay, linseed-oil meal gave better results.

Feeding ewes.—At the Colorado station breeding ewes fed alfalfa hay alone, in combination with corn, sunflower silage, and beet-top silage, maintained their weight as well and made cheaper gains than those fed alfalfa. There was very little difference in the weight of lambs from the different lots, or in their gain from birth to finish. The use of sunflower silage was found by the Oklahoma station to reduce the cost of feeding pregnant ewes, but the ewes fed sunflower silage were slower in lambing, and the lambs were not so good as those from ewes receiving corn silage. The ewes fed sunflower silage were not as good mothers. At the Arizona station feeding three-fourths of a pound per day of whole cottonseed to pregnant ewes produced no ill effects. The Montana station found 3 pounds of sunflower silage to be equal to 1 pound of alfalfa hay as feed for ewes.

Wool.—In studies at the Wyoming station the rate of change in the weight of wool was comparatively low where large quantities were stored in one place. The weather was found to have a very destructive influence upon wool fiber, but very severe treatments of the sheep's fleece with alkali salts had no measurable effect upon the strength of the fiber.

Goats.—At the New Mexico station crossing native does with Toggenburg bucks increased the milk yield in the first cross about one-third, and in the second generation an additional 15 per cent. The best native does gave about 2 quarts of milk a day. Two-year-old half bloods averaged about 200 pounds more milk for the first seven months of their lactation period than native does.

SWINE

Breeding.—A comparison at the Missouri station, through 12 generations of sows bred at the first heat period with sows bred first when more mature, showed that pigs from early bred sows were later in reaching an equal weight; but there was no eventual difference in the pigs, and more litters were secured from early bred sows. Early breeding did not influence the inheritance of ability to grow and fatten. Sows fed on a high plane of nutrition gave the biggest litters which made the fastest gains. Low-plane pigs grew in height but not in weight as fast as those on a high plane. The Minnesota station found that spring pigs made slightly better gains for feed consumed than fall pigs.

Maintenance requirements.—The Missouri station calculated the maintenance requirements of swine on the basis of surface area to be as follows: At a weight of 125 pounds, 3.028 therms per square meter; at 175 pounds, 2.838 therms; at 225 pounds, 2.807 therms; and at 275 pounds, 2.498 therms.

Pasture and forage crops.—At the Montana station alfalfa proved to be the most satisfactory hog pasture, and brome grass next. The

addition of tankage to a corn ration for pigs on alfalfa pasture did not show appreciable advantage. At the Arizona station the best gains were secured on alfalfa pasture with a self-fed grain mixture of 90 per cent Hegari and 10 per cent tankage. The poorest results were made on alfalfa pasture alone. The Pennsylvania station, in a three-year comparison of rape, rape and oats, and rape, oats, and peas, for hog pasture, found that rape alone gave decidedly the best results as to the amount of feed and pork per acre. The South Carolina station found neither peanuts nor sweet potatoes to be as profitable for pork production as for sale. At the North Dakota station, March farrowed pigs did better on pasture than May farrowed litters. At the Idaho station feeding of field peas resulted in considerable trouble and loss from paralysis of the hindquarters. Feeding with skim milk or tankage for a short time corrected the trouble. At the Wisconsin station there was no advantage from adding mangels and yellow carrots to a good ration for brood sows. When fed alone their food value was low.

Hogging down crops.—In experiments at the Missouri station corn pastured by hogs supplied with tankage produced more pork, and the hogs gained more rapidly than on any other combinations tested; tankage with corn alone or with corn and soy beans materially increased the rate and economy of gain; soy beans with corn did not completely take the place of tankage; and hogs on corn with soy beans alone made slightly more rapid gains than those on corn alone, but produced little if any more pork. Similar tests at the Kentucky station showed that hogging down corn and soy beans was not so profitable as hogging down corn alone, with free access to tankage. At the South Carolina station an acre of soy beans hogged off produced 400 pounds of pork. A comparison of hogging and sheeping down corn at the North Dakota station showed better financial returns from the former.

Miscellaneous feeds and supplements.—At the Nebraska station shoats receiving corn supplemented with tankage, alfalfa, or shorts gave better gains than those fed corn alone in a self-feeder. The largest and most profitable gains were made on corn and alfalfa. The Washington station found cane molasses equivalent in feeding value to barley when fed with pea forage. In tests made at the Kentucky station, stale buttermilk fed to hogs showed no bad effects if care was taken as to cleanliness of the utensils used. At the North Carolina station no fishy taste was noted in meat from hogs that had consumed as high as 82 pounds of fish meal in 119 days. At the Wyoming station three lots of pigs were fed garbage alone, barley alone, and various combinations of garbage and barley. The garbage lot made the cheapest gains, the mixed lot next, and the lot with barley alone next.

Mineral supplements.—At the Indiana station soy beans were not found to be as efficient as tankage, fish meal, or buttermilk as supplements to corn, apparently because of deficiency of mineral matter in both the corn and the soy beans. A homemade mineral mixture, consisting of 10 parts of wood ashes, 10 parts of 16 per cent acid phosphate, and 1 part of common salt, fed at the rate of about 10 pounds of the mixture per 100 pounds of gain, increased the rate of gain 30 per cent and decreased the food requirements 13 per cent. In experiments at the Iowa station gains were more rapid, the appetite better, and the feed

requirements per 100 pounds of gain less in the lot receiving the supplement. A mixture of salt and high-calcium limestone in equal parts proved to be as good as more complicated mixtures. In tests at the Oklahoma station lots of hogs fed the same ration with and without mineral supplements made practically the same gains, but those receiving the minerals had much thicker and stronger bones.

Soft pork.—The Georgia station found that 100-pound hogs fed in dry lot or grazed on peanuts for 60 days or more made soft pork and could not be hardened by feeding corn and tankage or corn and cottonseed meal for a subsequent period of 60 days or less, thus confirming results obtained by the North Carolina, South Carolina, and Alabama stations. Unthrifty hogs were generally soft, and the younger and smaller the hog the softer the carcass. Tests at the Florida station showed a marked variation in the melting points of the fat of pigs in the same litter, also in the fat of pigs from different litters sired by the same boar. There was some indication that a low or high melting point of the fat may be hereditary. In experiments at the North Carolina station with varying amounts of peanut oil added to a basal ration containing no peanuts, there were gradations of softness of the pork, increasing with the amount of oil fed. At the Texas station all of a lot of pigs grazed for 57 days on peanuts alone produced soft pork; 3 out of 10 of a second lot, grazed on peanuts for 30 days followed by milo chops and cottonseed meal for 27 days, killing soft. A similar lot, fed milo chops and peanut meal in the self-feeder, produced hard pork.

In tests at the Oklahoma station feeding peanuts and other concentrates together for 70 days gave better results than feeding peanuts for 40 days and a finishing feed for 30 days. At the Missouri station sunflower seed fed alone produced very soft pork. When it replaced as much as one-fourth of a ration of corn and tankage, the fat was not soft. The Texas station found that rice bran with equal parts of corn chops and 10 per cent of tankage can probably constitute 60 per cent of a ration of corn chops and tankage without having the carcass graded as soft. The California station found that rice by-products do not produce soft pork in all cases, this varying considerably with the individual.

POULTRY

Breeding.—From a study of sex-linked characters in poultry, the Connecticut Storrs station found it possible, with 2,000 chicks from crosses of barred and red fowls, to separate the males and females at the time of hatching. By numerous crossings it was found that barring (Barred Rock type) masked spangling, spangling was hidden by black, and the sex-linked spangling pattern was dominant over or masked buff. Black fowls were found to be genetically buff plus the factor for the extension of black, since buff fowls appeared in the second generation from the cross of black and Columbian. Continued brother and sister mating at this station has resulted in a noticeable decline in vigor and a general slowing down in the rates of all life processes, such as growth, sexual maturity, and beginning of egg production. Outcrossing at the Idaho station with introduced strains of White Leghorns indicated that mixing strains within a

variety should be avoided, since the results may be poorer than those obtained with the original strain.

Egg production.—Of 2,544 Single Comb White Leghorn eggs graded at the Idaho station between March and October, the average weight was 63.1 grams, or 5.1 grams higher than the average weight of eggs on the market. Of the eggs, 87.7 per cent were chalk white, 10.1 per cent slightly tinted, 1.7 per cent cream, and 0.5 per cent brown. In texture, 74 per cent were normal, 22 per cent rough, and 4 per cent porous. In shape, 85 per cent were normal, 5 per cent round, 5.6 per cent long and slender, and 4.4 per cent irregular. Of 1,214 eggs candled, 34 per cent were transparent, 56.6 per cent cloudy, 39.4 per cent dark red, and 0.6 per cent bloody. The Iowa station found that, with pullets in their first egg-laying year, vigor, vitality, and constitution are of prime importance as indicating future egg production, and that early maturity is absolutely essential. A survey of the State showed that about 34 per cent of the hens in farm flocks are culls, and the average annual egg production per hen in the farm flocks is only about 60 eggs, due partly to poor feeding.

In a comparison, by the North Carolina station, of fowls from the same hatchings raised in North Carolina and in Winnipeg, Canada, the southern birds laid more eggs than the northern birds. Leghorns selected and bred for egg production produced 1 dozen eggs for each 6 pounds of feed consumed; and other breeds, unselected, averaged 9.6 pounds of feed per dozen eggs. At the Missouri station, of 67 pullets which matured in less than 200 days, 19 (28 per cent) laid more than 200 eggs each the first year; of 135 which matured in from 200 to 250 days, 11 (8 per cent) laid more than 200 eggs; and no pullet requiring over 250 days to mature laid over 200 eggs.

The Oregon station found that there was a close correlation between March and April production and annual production. Late laying in the summer and fall did not always indicate a good layer. On the average, there was a rather consistent decrease in production each year. There appeared to be a correlation between rate of laying and the fat content of the eggs.

At the Texas station there was found to be direct correlation between egg laying and the pliability of the pelvic bones. Hens with a thin pliable skin lay a large number of eggs. Early molters were poor layers. There was a positive correlation between capacity and weight and between depth of body and weight.

Hatchability.—At the Connecticut Storrs station the selection of mothers on the basis of percentage of fertile eggs did not result in the isolation of true breeding strains, characterized by high and low hatching qualities. Inbreeding brought about a marked decrease in the hatching qualities of eggs. The gross characteristics of eggs played but little part in causing differences in the hatching quality, nor was size of egg related to hatchability, although large eggs from an individual did not hatch as well as small. Porous eggs did not hatch as well as dense-shelled ones.

At the Wisconsin station, pullets fed a ration of white corn and casein gave an average hatch of 15 per cent of the fertile eggs, but by using yellow corn instead of white this was increased to 23 per cent. When feed rich in vitamin, such as pork liver, was added to the rations, the average hatch for the white corn lot was 53 per cent and for the yellow corn lot 62 per cent. With skim-milk powder in

place of pork liver, the white corn lot gave an average hatch of 21 per cent and the yellow corn lot 50 per cent.

The Kansas station showed that the individuality of the hen may have as much to do with the hatchability of eggs and the vitality of chicks as does the character of the feed.

The Nebraska station found a direct correlation between the weight of the egg and chick weight at hatching, the latter being about 64 per cent of the egg weight. A positive correlation was found to exist between the size of egg and the vigor of the chick by the West Virginia station. The amount of carbon dioxid given off during incubation appeared to be directly proportional to the vigor of the chick. Data secured at the Oklahoma station showed that on an average the chick was about 32 per cent lighter than the weight of the egg. Abnormally large or small eggs did not hatch as well as medium-sized ones.

Feeding chicks.—The West Virginia station found that an unbalanced ration fed to young chicks reduced the mature live weight of the females, increased the period before laying the first egg, decreased the fecundity, and reduced slightly the average weight of the egg. In experiments at the Wisconsin station chicks fed on white corn, middlings, and skim milk died in a few weeks; but if one egg a day for each 30 chicks was added, normal growth resulted. When eggs were used there appeared to be no necessity or advantage in adding green feed to the ration.

Protein supplements.—At the Nebraska station a ration with 15 per cent protein either as meat scrap or buttermilk gave good growth. Chicks on a nitrogen-free diet were found to transfer protein from one part of the body to another. In seven years' tests at the Missouri station animal concentrates proved superior to proteins of vegetable origin. Vegetable proteins were found by the Ohio station to be unsatisfactory for chicks unless supplemented with suitable mineral mixtures. An inexpensive mixture of bone or rock phosphate 60 parts, limestone 20 parts, and common salt 20 parts, used at the rate of 2 per cent of the total ration or 4 per cent of the dry mash, increased the value of vegetable protein rations for growth and egg production more than 40 per cent at a cost of only about 2 cents a year for each chick.

The North Carolina station found that when the ground velvet beans were fed alone or with the pods they were injurious. When fed to the extent of 45 per cent of the fattening ration or 28 per cent of the mash for growing chicks, they were also injurious. At the Indiana station, soy-bean meal proved fairly efficient as a substitute for animal proteins but not quite equal to them. It was much improved by adding steamed bone or still better dicalcic or acid phosphate to supply the mineral deficiency. As a result of three years' test, the Kentucky station concluded that the mash mixture should contain at least 20 per cent of meat scrap to secure maximum production without forcing the birds.

Tests at the Oklahoma station showed the most economical amount of tankage in the ration to be 25 per cent. The average weight of the eggs from hens receiving this amount was about 3 grams greater than that of eggs from hens receiving no tankage. The Kentucky station found that when sour skim milk was kept constantly before the birds, it was not necessary to feed a dry mash.

At the Idaho station it was found that this material could entirely replace meat scrap in the ration. At the Iowa station fresh buttermilk proved superior to other forms.

Grits and lime.—The Kentucky station found that a hen will retain the necessary quantity of grit, and that this is apparrently as effective as new grit. Limestone and rock phosphate served the same purpose and to the same extent as grit in the gizzard. The hens utilized the lime in calcium carbonate for the production of both eggshell and bone, but the lime in tricalcium phosphate was only utilized for growth of bones and not for eggshell formation. Calcium starvation was not the determining factor in the production of shell-less eggs.

Artificial lighting.—Best results were obtained at the Montana station by lighting in the morning from 5 o'clock to daylight. Hens that had morning light laid nine more eggs each during the year and gave extra returns of 54 cents each after paying the cost of the extra feed and lights. At the North Carolina station, keeping birds continuously under 14 hours of light each day caused overlaying and reduced egg production for the two succeeding years. Best results were obtained at the Utah station with morning light only, next best with morning and evening light. With evening illumination only the birds did not appear to be anxious for their feed and were restless and tired.

DAIRYING

Inheritance.—In color inheritance studies with Jersey cattle at the Kentucky station there were found to be three separate and distinct determiners controlling tongue, body, and switch color. Solid body color was dominant over broken body color, black tongue over white, and black switch over white. Yellow nose appeared to be recessive and gray color was dominant over all other coat colors. At the Maine station, in the crossing of Holsteins, Jerseys, Ayrshires, and Aberdeen-Angus, representing three levels in milk production, it was found that the crossing of a lower level with a higher tended to give a considerably higher production than the average for the lower members of the cross; but the reverse was true of the butterfat percentage, there being a decrease over that of even the lower members.

Milk production.—Analysis of a large number of milk records at the Maine station showed that sire and dam transmit milk production equally to the daughter and that 80 per cent of the variation in milk yield is due to controllable hereditary causes, the same applying to butterfat percentage.

Open Jersey cows slightly excelled pregnant ones in the production of milk and butterfat in studies at the Kentucky station. Two-year-olds produced 74 pounds of milk and 73 pounds of butterfat for every 100 pounds produced by mature 7-year-old cows. Three-year-olds produced 81 pounds, 4-year-olds 94 pounds, 5-year-olds 92 pounds, and 6-year-olds 96 pounds of butterfat compared with 100 pounds for 7-year-olds. No correlation was found between the production of milk and butterfat and the size and shape of the escutcheon and the amount or color of body secretions.

Leaving one-fourth of the milk normally produced in the udder at the last milking preceding the regular semiofficial test was found by the Pennsylvania station to slightly increase the yield of milk and butterfat in the following two-day test.

Studies at the Missouri station showed that, other conditions being approximately the same, the lower the environmental temperature the higher the percentage of fat in cows' milk, there being approximately 0.2 per cent increase in the fat for each decrease of 10° F. between 30° and 70°. No definite correlation was found between total solids and temperature. Sponging with cold water (50° F.) at two-hour intervals through the day tended to increase the percentage of fat and total fat in the night's milk. It was noted, however, that after a time this increase was not obtained, indicating that the animals may have become adjusted to the treatment. Under ordinary conditions of management of dairy cattle, independent of the season or character of the feed, there was a noticeable decline in the percentage of fat from the first to the second and sometimes to the third month of lactation, followed by a gradual increase, becoming more pronounced during the last month of lactation. The percentage of fat tended to be lowest in the summer months, then gradually rose and reached a peak during the winter months. When the different seasons of the year were accompanied with varying temperatures the influence of the season on the percentage of fat is greater than the advance of lactation. The average daily milk flow increased slightly through the second month and then gradually decreased until the end of lactation. If cows were milked immediately after coming into the barn after exercising, the difference in fat between the first and last portion drawn was from 3 or 4 to 7 or 8 per cent; but if the cows stood quietly for a while the difference might be as high as from 1 to 12 per cent. With Guernseys there was a gradual decrease in milk production after the first month of lactation, which had dropped about 50 per cent at the end of 12 months, but there was a slight increase when they went on pasture. Cows freshened in the fall produced the largest amount of milk for the year and the least when freshened in June, July, or August. A cow was found to reach her maximum production at 8 years of age.

Composition and properties of milk.—Lipase is not a normal constituent of milk, and its presence results in bitter milk, according to investigations by the Minnesota station. The depth of the cream layer on raw milk was found to be correlated directly with the viscosity of the milk.

That the energy value of milk solids is a constant but the fat may vary was shown by studies at the Illinois station.

Feed influenced the heat coagulation of milk materially in experiments at the Wisconsin station. Fresh milk from a cow on dry feed coagulated consistently at 246° F. in two or three minutes. With this same cow on pasture the milk did not coagulate at 246° in 30 minutes.

The methylene blue method for testing the bacterial content of milk, according to preliminary tests reported by the New Hampshire station, may serve as a satisfactory index of keeping quality and requires less apparatus, time, and technique than the plate method.

105313—24——5

It was found that a reduction time of three hours or less corresponded to a bacterial count of 500,000 or more per cubic centimeter; four to seven hours, 150,000; and eight hours or more, 25,000.

Nutrition and growth.—In studies on the protein requirements of dairy cows carried on by the Vermont station it was found sufficient to use a ration carrying a pound of digestible protein a day per 1,000 pounds of live weight for a low-milking cow and 1.5 to 2 pounds for a better producer. It was unnecessary for milk purposes to increase the digestible protein of the ration to 2.5 pounds per day per 1,000 pounds of live weight. Cows receiving for four and one-half years barely a pound of digestible protein per day per 1,000 pounds of live weight were not injured in respect to their physical condition, nor was the high-protein ration of 2.5 pounds in any respect injurious; but the cows receiving the high-protein ration tended to drop out earlier and to last a shorter time than those fed a medium (2 pounds) or a low (1.5 pounds) protein ration. Cows on a very low-protein ration after four and one-half years lost about 8 per cent of their live weight. Those on low and medium rations gained in body weight up to about 10 years of age, whereas cows fed a high-protein ration put on relatively little live weight and tended to lose slightly in weight after the seventh year. In milk production the high-protein ration cows averaged 3.5 per cent more product than the low and 2 per cent more than the medium, while the latter produced 2.5 per cent more than the low-protein ration cows. Short, alternate feeding tests were found to give results parallel to long-time tests, if carefully carried out and enough animals were used.

The Vermont station experiments also showed that the protein utilization varied profoundly with the ration changes in respect to the nutrient. In several instances, using the old-time 0.7 pound digestible protein maintenance allowance, recovery exceeded 100 per cent. Protein recovery was essentially identical for thin and rich milking cows. The results obtained suggest somewhat lower digestible protein needs than were set forth a generation ago. The total solids and fat content of the milk were unchanged by changes in rations, but to a slight extent their albuminoid content was changed, parallel to the protein content of the ration. Apparently, in the economics of the milk and butter production, a more nitrogenous ration is to be preferred. Cows bred to calve 12 to 14 months after calving tended to give, month by month, nine-tenths of the yield of the preceding month for nine months, then five-sixths of the yield of the preceding month to the end of the lactation period. Cows which had aborted tended to give, month by month, thirteen-fourteenths of the yield of the preceding month. Abortion was found to decrease the average milk flow one-fourth to one-fifth, and the total solids, fat, and albuminoid percentages increased about 0.2 per cent. If no material alteration occurred in the digestible nutrient intake, abrupt changes in digestible protein intake were not likely to be reflected in the milk yield.

Early stunting of calves did not appear to prevent later growth, according to observations at the Indiana station; but this later growth was made at a very high cost, because of the large amount of feed consumed during full feeding.

For medium producing cows, alfalfa hay was found by the Iowa station to supply sufficient calcium to take care of the requirements

for this element in the body. With a ration of timothy hay, however, a negative calcium balance prevailed. Alfalfa hay that was a year and a half old failed to produce a positive calcium balance, giving evidence that green plant tissues contain some substance that favorably affects calcium assimilation in the animal body.

Calf feeding.—Excellent results in feeding calves were obtained at the Arizona station with the use of a homemade substitute for milk, consisting of 2 parts finely ground corn meal, 1 part mill-run wheat bran, 3 parts wheat middlings, 2 parts oat groats, 1 part linseed-oil meal, 0.5 part blood meal, and 0.2 part ground bone meal, with 1 quart of milk a day for the first month. Feeding calves twice a day was found by the Idaho station to be fully as efficient as feeding three times a day and pasturing to be more economical than dry-lot feeding. At the Washington station calves were successfully raised on condensed buttermilk from the age of 3 weeks up to 4 to 6 months, making satisfactory gains of from 1.3 to 1.6 pounds per day. No trouble was experienced with scouring.

Milking machines.—Studies at the Texas station showed that with the same amount of care milk taken by hand was slightly lower in bacterial count than milk taken by machine. The yield of milk was not materially affected by either method if the cows were milked clean. It is considered good policy to strip the cows by hand after milking with the machine, although this may not be necessary with the best type of machine. One man with two single-unit machines was able to milk about twice as many cows in a given time as one man milking by hand. The economic advisability of the milking machine for any individual dairyman appears to be determined largely by the intelligence of his labor. The South Dakota station found no injury to the cows after several years' use of milking machines. Stripping the cows was an absolute necessity with all types of machines, and when this was taken into consideration there was not much saving over hand milking in small dairy herds. Under some conditions the bacterial count of the milk was found to be considerably increased, especially in the type of machine using double units, one set of cups being idle while the other was in use.

Home-grown feeds.—At the Wisconsin station a comparison of a home-grown feed, consisting of alfalfa hay, corn silage, and a concentrate mixture of corn and oats, with the same ration to which was added linseed and cottonseed meal, showed that the first maintained the yield of milk and butter fat as well as the ration containing the purchased linseed and cottonseed meal.

Silage for dairy cattle.—In a 120-day feeding test with dairy cows, at the Idaho station, sunflower silage produced 11.4 per cent more milk and 1.07 per cent less butterfat than corn silage. Figured on the basis of yield per acre, the difference in favor of the sunflower silage was considerable. Data secured at the Illinois station showed that sunflowers ensiled at a comparatively immature stage of development, when 20 to 25 per cent of the plants began to show rays of the blossoms, made more palatable and more digestible silage, and that such silage maintained milk production more nearly on the level with that produced with corn silage than when harvested at later stages of growth.

At the Oregon station there appeared to be little difference in the feeding value of sunflower, corn, and oat and vetch silages. At first

the sunflower silage was not readily eaten; but during the year the milk production of cows fed sunflower silage was the highest, as were the total nutrients per pound of milk and the total percentage of butterfat, oat and vetch silage being second in this respect and corn silage last. No flavor due to the feeds was detected in the butter from any of the lots. There seemed to be a slight tendency on the part of the sunflower silage to give a tallowy butter. The iodin values were: For sunflower silage butter, 29.317; corn silage butter, 26.965; and for oat and vetch silage butter, 26.247; indicating a larger content of olein in the butter made from milk of cows fed sunflower silage.

In comparative tests at the Montana station cows receiving corn and sunflower silage gave practically the same results as to milk and butterfat yield; but as the sunflowers produced about three times the tonnage of corn, they were the more economical feed. At the Pennsylvania station pure sunflower silage produced 86.4 per cent as much milk as good-quality corn silage. A silage made of half corn and half sunflowers produced 96.2 per cent. Corn silage was found to be superior to oat-and-pea silage for milk production. Silage from mature and medium mature corn proved to be better for milk production than that from immature corn. In a comparison of hay alone and hay with oat-and-pea silage for roughage with the same grain ration, the average daily milk production showed a decided advantage from feeding silage.

The Wyoming station found that sunflower silage was almost equivalent, pound for pound, to corn silage in the production of milk. Considering the cash cost of producing sunflower and corn silages on the basis of their acre yields, dairy cows produced both milk and butterfat more cheaply on sunflower silage, although the yield fell off slightly. Both sunflower and oat-and-pea silages were found to be about equal in value for wintering calves, but the oat-and-pea silage cost considerably more.

A comparison of corn silage with sorghum silage for milk production, at the South Carolina station, showed the latter to be 96 per cent as efficient as corn silage for producing milk, about 97 per cent as efficient for producing butterfat, and 88 per cent as efficient for maintaining body weight. Sorghum produced a heavier tonnage of silage than corn, which gave it a little advantage.

At the Minnesota station cows were fed moldy silage for four months without any injurious effects, nor was any injury noted in feeding cultures of molds in quantities far in excess of those that would be obtained in silage.

Protein supplements.—Cottonseed and linseed meal when fed in connection with alfalfa hay, corn silage, and corn and oats gave no increase in milk production at the Wisconsin station, indicating that protein supplements are not needed when a well-balanced ration is fed.

Velvet-bean meal fed to dairy cows apparently had no effect in changing the melting point of the butter fat in the milk, in tests made at the Florida station. Comparative tests, at the Mississippi station, of cottonseed meal and velvet-bean meal, both alone and mixed, showed that velvet bean and pod meal gave the largest returns and a mixture of cottonseed meal and velvet bean and pod meal the next largest. Three pounds of soaked velvet beans and pods appeared to be fully equal in feeding value to 2 pounds of cottonseed meal. In

feeding tests at the North Carolina station, velvet bean meal was not very palatable and the cows went off feed more quickly and produced a little less milk than on cottonseed meal. At the South Carolina station no bad effects were noted in the physical condition of cows receiving a large amount of velvet-bean meal, the results indicating that the meal maintained the body weight and milk flow quite as well as other feeds.

No effect on the flavor of the milk from feeding fish meal was noted at the Florida station, but the cows did not relish it, the maximum amount a cow would eat varying from 1 to 1¼ pounds per day.

Butter.—Butter made from ripened acid cream, at the Iowa station, scored higher at the beginning of the storage period than that made from sweet cream, and maintained this high score for 2 or 3 months, but at the end of 9 months' storage the sweet-cream butter was rated higher. In studies of the effect of heating and neutralizing cream, the best results were obtained when the cream was heated to 170° F. for 20 minutes. The keeping quality of butter was considerably improved by neutralizing the cream.

Tests at the Vermont station of storing butterfat at low temperatures showed that butter made from such stored fat was of better flavor than that of stored butter at the end of 7 and of 12 months.

The average cost of producing butterfat was found by the Arkansas station with three breeds—Holsteins, Jerseys, and Ayrshires—to be 42 cents per pound. The cost of producing 100 pounds of milk was $1.61 with Holsteins and $2.08 with Jerseys and Ayrshires.

The Wisconsin station found the fishy flavor of butter to be due largely to chemical decomposition of lecithin into trimethylamin, the factors favoring this condition being high acidity and high salt content in butter, combined with oxidation resulting from overworking in the presence of metallic utensils. Whey butter and creamery butter scored about the same, but the former kept longer.

Ice cream.—When the percentage of lactose in solution in the cream exceeded 10 per cent, the Indiana station found sandiness invariably occurring. Ice cream containing more than 12 per cent of milk solids-not-fat usually developed sandiness. Binders decreased sandiness but did not eliminate it. Commercial gelatin was found to be very variable in character and in its effect on the quality of the ice cream.

A comparison by the Nebraska station of mixtures containing from 6 to 20 per cent of butterfat, all other constituents and conditions being the same, showed that 18 and 20 per cent fat mixtures produced the best results from the standpoint of yield, consistency, and flavor. The lower percentages of fat yielded ice cream of good body but lacking somewhat in flavor.

The Missouri station found that increasing the butterfat in the cream mixture uniformly decreased the specific gravity and gradually increased the viscosity. The time required for the mixture to begin to freeze varied directly with the fat content, and the time required to whip the mixture was decreased, the net result being a decrease in the total time required to freeze mixtures with high fat contents. The most desirable flavor, body texture, richness, and appearance were obtained with a 10 and 12 per cent mixture. Varying the fat content had no effect on the freezing point. Increased increments of skim milk and of condensed and evaporated milk depressed the

freezing point. When the temperature remained constant, the body fat had no influence on the hardness. The higher the percentage of fat the longer the cream took to melt at 86° F. When scored after five days, that with 10 to 12 per cent of cream gave the best results. The overrun percentage increased up to 10 per cent of butterfat and then decreased. Skim-milk powder, condensed milk, and evaporated milk lowered the freezing point, but gelatin, gum tragacanth, etc., had no effect on it.

DISEASES OF LIVESTOCK

Infectious abortion.—Infectious abortion continued to be a prominent subject of investigation by a number of the experiment stations.

A vaccine prepared by the Kentucky station proved effective with mares, but of doubtful value with cows. In no case where mares were vaccinated as a prophylactic measure did the disease occur. Uninfected mares in infected herds were successfully immunized against the disease. The vaccine caused some stiffness of the neck, which disappeared in a few days. A hyperimmune serum was prepared but did not appear to have as much value as the vaccine.

Four years after inoculation with *Bacillus abortus* cows were found by the Missouri station still to be carriers of the infection and capable of infecting nonreacting pregnant cows through uterine discharges, afterbirths, etc. Nonreacting pregnant cows, allowed to mingle freely during their full gestation period with the inoculated cows, which had been bred a week or more after the younger animals, carried their calves to full term and did not develop a positive reaction. It appears that both cows and sows may become carriers and remain permanent reactors, as a rule, although a few may outgrow it. The transmission of immune bodies was found to occur in cattle as well as in swine, and complement-fixation bodies were taken by the calf through the milk.

As it is known that unbred heifers may become infected and established reactors, the Connecticut Storrs station made a study of other means of infection than from the bull, but did not succeed in bringing about infection by the administration of suspensions and cultures of *B. abortus* or of vaginal secretions through the mouth, other chances of infection being eliminated. Infection was repeatedly accomplished, however, by superficial injection into the urethra and by direct application to the inner surface of the vulva.

Animals are most apt to abort during the prenancy in which the initial infection is received, according to the Oregon station, and animals infected during their first pregnancy are more apt to abort than those infected during later ones. Animals from which the udder was surgically removed and then bred and confined with an infected cow became positive, but the reaction gradually diminished. The indications are that the habitat of the organism is in the udder and pregnant uterus only and is not in other portions of the animal's body. Accurate records of herds in the State show that the disease has not lost its virulence in seven years. There is found to be much more mastitis in infected than in abortion-free cows. Of 1,478 blood samples from various counties in western Oregon, 37.7 per cent were positive.

The average time required for abortion to result after infection was found by the Wisconsin station to be about 23 days in the sow and

about 58 days in the cow. It seems to be a more or less self-limiting disease in that a naturally acquired infection is usually followed by immunity, which will protect some sows for a long time; and the breeding efficiency of animals which have aborted is not necessarily impaired, although this depends somewhat on the individual.

A number of nonvirulent strains of *B. abortus* and many strains that decline in virulence after cultivation for several generations on an artificial medium are reported by the Michigan station. Attempts to produce the disease artificially or to secure immunization by means of cultures gave variable results at this station because of the variation in the virulence of the strains and the immunity to the disease of some of the animals tried. A simple plating method of detecting the organism in the milk has been worked out, which makes it possible to identify and isolate carriers. The investigations of this station inditate that the disease is transmitted by ingestion of infected material and not by the bull. Attempts to inoculate the udder through the ceats gave negative results.

Studies by the Michigan station on the susceptibility of swine to bovine infectious abortion gave only negative results. At the Illinois station the disease was induced in swine by intravenous and subcutaneous injection of abortion bacilli as well as by feeding the bacilli from cases of swine abortion. In all cases examined by the Missouri station pigs from positive sows were negative before nursing and positive afterwards. See also page 119.

Hog cholera.—Exposure experiments were carried on at the Indiana station with the following results: In two sets of pens in the field separated 4 and 8 feet apart, respectfully, one pen in each set containing cholera pigs and the other healthy nonimmune pigs, visible symptoms of cholera were manifest in the controls on the sixteenth and nineteenth day, respectively. In pens in a small house separated only by cheesecloth, one containing cholera pigs and the other healthy animals, the latter were well on the thirty-third day when their susceptibility was proved by inoculation. Healthy pigs placed in a field pen three and four days after sick and dead cholera pigs were removed from it were well on the thirtieth day, and their susceptibility was then proved. In a building having a concrete floor, 6 lots of 4 pigs each were placed in pens which were heavily bedded with straw and sprinkled with cholera blood 1 to 6 days before turning in the pigs. One or more pigs showed visible signs of cholera on the eighth day. Repeating this with outdoor pens, putting the pigs in 4, 5, and 6 days after infecting the pens, all the pigs were well on the fourteenth day. Feces and urine collected from cholera pigs killed on the fifth day after inoculation and showing visible symptoms did not produce cholera when fed to susceptible pigs. Of 2 lots of susceptible pigs fed with feces from a pig killed on the seventh day after inoculation, 1 pig developed the disease, while 2 other lots fed urine from the same pig remained well. Post-mortem examinations showed that hemorrhagic lesions occurred as early as the fifth day and intestinal ulcers as early as the ninth day after inoculation.

At the Minnesota station a test of the length of time that serum-virus treated pigs act as carriers and disseminators of cholera showed that susceptible pigs placed with such treated pigs between the fourteenth and twenty-first day after treatment contracted cholera, but after the twenty-first day no exposed pig contracted the disease.

Studies on the natural immunity of suckling pigs carried on at the Maryland station showed that pigs inoculated at birth were immune as long as they were nursing immune mothers, but developed the disease when they ceased to nurse.

The North Dakota station found that when the serum-virus was precipitated with sodium tungstate and sulphuric acid, allowed to stand and filtered through ordinary filter paper, a protein-free nonvirulent filtrate was obtained; but the precipitate was virulent. Similar tests with swamp-fever virus showed its virulence to be completely destroyed by the chemicals involved in the precipitation.

Other swine diseases.—Losses from diarrhea in shoats, at the Kentucky station, were almost completely overcome by improved sanitation, modification in the administration of serum and virus for permanent immunization against hog cholera, and the use of a bacterin made from microorganisms isolated from infected individuals. In studies of dysentery in swine, the Indiana station found the virus to be present in the stomach and colon, but not in the lungs, spleen, liver, kidneys, or heart. Posterior paralysis of swine was found by the Minnesota station to be due to a deficiency of calcium in the diet.

Hemorrhagic septicemia.—In all attempts by the North Dakota station to produce this disease in hogs by feeding the organism even under conditions of gross neglect of hygiene and sanitation, with improper and deficient food, no method of inoculation was found which would regularly induce an infection in hogs. Of 12 cholera-infected pigs, 6 showed the presence of the bipolaris bacillus, but the harboring of this organism in the lungs did not of itself appear to alter the course of an infection of hog cholera. The investigations of the station indicated that there are specific types of the organism attacking different animals, which may be designated as the bovine-swine, ovine, avian, and rabbit-cavia types.

Vaccine made from attenuated living organisms was found by the Oregon station to control the disease within a few days. The station recommends the vaccination of all young animals, both sheep and cattle, each year as a preventive.

The Nebraska station found that, however marked the protective qualities of a serum may be, the passive immunity conferred by it is of a rapidly evanescent character and completely vanishes within a week. Commercial sera were found to vary widely in their power to secure immunity, but in the best the period of protection was short, being only from four to seven days as a rule. Animals treated with serum and virulent cultures did not become actively immune and succumbed to subsequent injections of the virus.

A comparison of the value of live and dead septicemia organisms for vaccination at the Colorado station showed that the live organisms give the greater immunity.

Hemorrhagic disease of cattle.—Station work on this disease is noted on page 120.

Anthrax.—The Louisiana station found that anthrax was transmitted from infected guinea pigs to experimental animals by *Tabanus quinquevittatus*, *T. lineola*, *T. costatus*, and *T. fuscicostatus*, the highest percentage of infection, about 50 per cent, being obtained with the first-mentioned species when the flies were allowed to feed on sick and then on healthy pigs. The percentage of infection was highest in June and July and none was produced in September and October.

Several species of flies gave negative results. About two-thirds of the infested pigs showed no external symptoms, but died with internal symptoms within 48 hours after exposure to the infected flies. The organisms were still virulent in cultures in sterile and unsterile water after 12 years, in milk cultures after 10 years, and in dog feces after 9 years. Commercial vaccines 5 years old showed no deterioration. Fish in inoculated solutions were killed by the disease, and the dead bodies were found to carry the organism. The Oregon station demonstrated that the anthrax organisms may be recovered from the ear, thus making it unnecessary to open a carcass in order to secure material for examination.

Tuberculosis.—Particularly notable work on tuberculosis was reported during the year by the California station on the longevity of the tubercle bacillus, and by the Minnesota station on the importance of secondary or incidental reactions of early tuberculin tests from the standpoint of diagnosis. For further review of station work on this subject, see page 119.

Swamp fever.—The North Dakota, Texas, and Wyoming stations reported especially notable work on this disease during the year. For a review of the subject, see page 120.

Necrobacillosis.—The Wyoming station continued its work on this disease. This and other station work on this disease is noted on page 120.

Texas fever.—Tests made at the Texas station showed that Brahman cattle may be artificially inoculated with Texas fever and that they are also capable of carrying the infection for a period of at least 83 days.

Mastitis.—From a study at the Oregon station of the udder flora of animals showing a history of infectious mastitis, it appeared that most of the animals examined harbored an organism identical with streptococcus mastitis indefinitely after recovery from the disease. A high percentage of garget was found in animals that reacted to the complement-fixation test for abortion. One form of matitis in cows was found by the Maryland station to be a water-borne disease and apt to be carried on milking machines. By ceasing to use the machines, the disease was eliminated. The causal organism was found to be *Pseudomonas pyocyaneus*, which is not usually pathogenic.

Infectious diarrhea of cattle.—An outbreak of this disease studied by the Louisiana station was found to be apparently caused by a protozoa of the Prowazekia group. A commercial preparation of sulphocarbolate fed for two or three days during the earliest stages seemed to effect a cure in many cases, but it was not found to be a preventive. The disease is believed to be water borne.

Botulism.—Animals at the Kentucky station affected with what was diagnosed as forage poisoning recovered when large doses of magnesium sulphate were administered. In a study of an outbreak of a disease in chickens and ducks with the clinical symptoms of botulism at the Illinois station, an anaerobic, nonmotile, Gram-positive, spore-forming organism was found, which when cultured and fed to guinea pigs induced symptoms resembling botulism, but which were not controlled by A and B botulinus antitoxin, suggesting the existence of a third type, C.

Sheep and goat parasites.—Investigations on the stomach worms of sheep at the Connecticut Storrs station showed that the parasites

not only suck the blood but also introduce a toxin. Nicotin sulphate in suitable doses, with previous dosage with Epsom salts, proved a very efficient treatment. Treatment with copper sulphate alone was not satisfactory, although the Texas station used it with good results with goats and less satisfactory results with sheep. The Oklahoma station found that the larvæ hatch out on the ground and molt in a few days, after which they reach the infectious stage and migrate to blades of grass wet with dew or rain, especially at night or during diffused light. When eaten by grazing animals they reach maturity about three weeks after reaching the stomach. The larval worms may live for several months and withstand adverse weather conditions—freezing, thawing, and drying—without much injury. The station recommends copper sulphate with tobacco as a remedy.

In life-history studies of the lungworms of sheep, the Oklahoma station found the course of migration of the larval worms to be from the alimentary canal to the lungs by way of the blood and lymph vessels. The larvæ remain for a time in the lymph glands and then pass into the blood stream, by which they are carried to the lungs. Here they penetrate the capillaries, which they break down, and enter the air spaces. They later work their way to the larger air spaces, where they grow to maturity. The larvæ were fed to lambs for several days, and 20 days later the worms were found distributed through the blood, lungs, lymph, liver, and other organs. Negative results were obtained by subcutaneous inoculation.

Poultry diseases.—Investigations at the Kansas station on bacillary white diarrhea showed that the hatchability of eggs from reacting hens was from 12 to 20 per cent less than from the nonreactors. The albumen of the eggs from infected hens caused agglutination in affected birds. This material can, therefore, serve to test the reaction of the hens.

The Oregon station found that in cases of coccidiosis, treatment with hydrochloric acid added to the drinking water in the proportion of 1 part to 500 gave good results. Attempts to transmit the disease by feeding the intestines of infected fowls to healthy ones were unsucessful.

Studies at the Colorado station of the sod disease of chickens, so called because it apparently does not occur on irrigated land or on dry land where the sod has been broken up and cultivated, did not definitely show its cause. It appeared to be infectious, but attempts to isolate the causal organisms gave negative results. The disease starts as blisters between the toes, with the formation of scabs, the feet become swollen and tender, and the toes may drop off. The symptoms sometimes appear on the head also. The mortality may even run as high as 90 per cent, but is usually not over 20 per cent. It is most prevalent in summer. It usually affects small chicks worse than adults. Dipping the feet and bills in kerosene was found to be an effective treatment.

Life-history studies at the Kansas station of the fowl nematode (*Ascaridia perspicillum*) showed that the eggs when passed by the fowl developed to the infective stage in moist ground in about two weeks during the spring, summer, and autumn. When these eggs were swallowed by young chicks, they hatched in the small intestine and developed to maturity in four to six weeks. Four generations of worms may develop from March to December. In the presence of

ample moisture, normal development of the embryos was retarded in the egg when the temperature reached and was maintained at from 40° to 44° C. for a few hours, but most of such eggs reached an infective stage. With temperatures of from 45° to 49° very few reached this stage. The eggs can withstand freezing. Although larvæ of the large roundworm migrate from the intestines through the tissues of the host to the lungs, from which they are returned to the stomach, the chicken roundworm seldom migrates thus. The Minnesota station found that a mixture of 20 parts of oil of turpentine with 1 part of chloroform, introduced into the crop of the fowl with a catheter, was from 80 to 100 per cent effective as treatment. At the Oklahoma station infection was produced by feeding eggs to chicks. The larval worms were found to migrate in the chick's body, but only a few reached the lungs. Feeding larval or longer worms to chicks did not produce infection. Treatment with 1 per cent copper sulphate solution with tobacco eliminated from 60 to 70 per cent of the worms.

Hookworms.—The Kansas station found that eggs of the human hookworm will pass through the digestive tract of the pig uninjured and will develop afterwards, but after passing through the chicken only about 10 per cent will develop, owing to the action of the gizzard.

Poisonous plants.—Studies of plants poisonous to livestock and their effects, in large part continuing previous work, were reported by a number of stations, notably by the Colorado station on the whorled milkweed (*Asclepias galioides*); the Indiana station on white snakeroot (*Eupatorium urticæfolium*); Montana station on eradication of loco (*Astragalus blankenshipii*); and Nevada station on seaside crowfoot (*Halerpestis cymbalaria*), western goldenrod (*Solidago spectabilis*), saltbushes (*Atriplex* spp.), mountain laurel (*Kalmia microphylla*), rabbit brush (*Tetradymia glabrata*), larkspur (*Delphinium* spp.), and clover sage (*Artemisia spinescens*). See also pages 116–119

RURAL ECONOMICS

Why some farms pay.—The Wisconsin station, in a study of why some farms pay while others with similar soils and topography and the same seasonal conditions and markets do not, found that large farms have generally been heavier losers than small ones. The two outstanding ways in which the farms that have made money differed from the others were the increased number of sources of income (diversification) and the greater production of the dairy herd. In one area investigated the average production of milk per cow was 5,600 pounds, which is not a paying proposition. As the average production per cow increased from an average of 4,625 pounds in the lowest herd to 8,138 pounds per cow in the best herd, the average farm income increased from $476 to $1,205, and the cost of milk produced in this case decreased $1.19 per 100 pounds.

Farm management.—Studies on 181 farms by the the Idaho station showed that chief factors contributing to the success of most successful farms were (1) the production of high crops yields, (2) the selection of the most profitable crops to grow, (3) marketing the crops early in the season before prices had fallen materially, and (4) keeping expenses at a low level without interfering with the production of high crop yields.

Livestock versus grain farming.—In a comparison of livestock and grain farming at the Ohio station, the average yields were distinctly less in grain farming than in livestock farming. The Kansas station found that, as a rule, poultry gave good returns on labor, amounting to from 40 to 90 cents per hen.

Cost of production.—In studies at the Missouri station it was found that the average cost of production in the State in 1921 was $2.26 a bushel for wheat, 63 cents for oats, and 62 cents for corn. As the yield increased the cost per acre increased; but the cost per bushel decreased until the optimum yield was reached, when it again increased.

The Washington station found that the cost of milk production varied on individual farms in that State from $1.81 to $4.56 per 100 pounds. In 1920 a price of $3.40 per 100 pounds would have covered the cost of producing 90 per cent of the total milk produced by the herds studied. The basic requirements for producing 100 pounds of milk were found to be 17.7 pounds of grain, 38.2 pounds of hay, 47.1 pounds of succulents, 3.1 days' pasture, and 2.3 hours of man labor. The studies indicated that the cost of producing milk may be materially reduced by the use of better stock, better feeding, and better labor management.

On the basis of data from 200 farms, the Illinois station found that 1.38 hours of man labor and 2.02 of horse labor were required per ton of silage. By efficient management, 22 of the farms put up silage with an expenditure of less than 1 hour of man labor and 1½ hours of horse labor per ton.

In a study of the cost of producing wheat, oats, and corn at the Kansas station, the use of tractors was found to give a higher cost per unit of yield. The Indiana station found horse power more economical than tractors.

Marketing potatoes.—Investigations at the North Dakota station showed that farmers do not exercise sufficient care in sorting and grading their potatoes to meet the requirements of the markets. Freight haul on North Dakota potatoes was found to be over 40 per cent of the gross returns of the crop.

TECHNOLOGY

Flour and bread.—The viscosimeter was found by the Minnesota station to be an accurate and rapid means of measuring slight changes in the colloidal properties of flour. Suspensions of flour in water were found to be extremely labile systems, affected by many factors which influence the viscosity of emulsion colloids. Maximum viscosity, due to action of acids on flour, was obtained with an acidity of pH 3, regardless of the nature of the acid. Maximum viscosity with alkalis occurred at approximately pH 11. Glutenin was the protein mainly responsible for the inhibitional power of flour and gluten. The rate of maltose production in dough was very regular at any given temperature. As the time of fermentation increased, the acidity of the dough likewise increased, causing a considerable increase in the rate of maltose production. The addition of malt preparations to doughs increased the volume of the resulting breads and the baking strength of the flour.

Shrinkage in the curing of meats.—Studies at the Missouri station showed that in hams there was 3.5 per cent shrinkage with old hogs and 12.5 per cent with young ones, with little difference between hogs of the same weight. In all cases, the greater shrinkage was with young animals. The dressing percentage on lean steers was 52 and on fat steers 62, the shrinkage in the cooler from lean steers being 1.2 per cent and from fat steers 1.6 per cent.

Sugar and sirup.—In the clarification of cane juice, the Louisiana station found that little advantage is to be gained by artificially changing the hydrogen-ion concentration of natural juice by the addition of acid or alkali after simple clarification with an inert medium, such as diatomaceous earth. Any adjustment of hydrogen-ion concentration may better be made during clarification. A study of the precipitate which forms in greater or lesser amount in the sirup resulting from concentration of cane juice, regardless of what method of clarification is employed, showed that a large part of the inorganic constituents of the precipitate is derived from soil clinging to the cane when it is received at the mill. No way of forcing this precipitate to come out in the ordinary course of clarification has been found.

In studies of sugar deterioration, the Louisiana station found that the extracts from some of the species of mold fungi occurring in sugar invert sucrose at densities beyond the maximum to which mold itself is active, indicating the possibility of sugar deterioration occurring in the absence of living organisms. Of 30 species of mold studied for their inverting power on cane sugar, *Aspergillus repens*, *A. niger*, and blue aspergillus were found to be most active. It was noted that in the presence of toluene no inversion from mold spores took place. Gum levan, produced by bacteria in sucrose solutions, was found to be formed directly from sucrose and not from the product of its inversion. Its formation was decreased by the presence of invertase in proportion to the activity of this substance. Formation was greatest when the hydrogen-ion concentration was least favorable to inversion. The reaction of limed cane juice was more suitable for gum levan formation than that of either raw or sulphured juice. Two bacilli, *Bacillus mesentericus vulgatus* and *B. furcus*, were found to have, to a slight degree, the ability to form gum levan, and this was increased when the organisms were grown in a sucrose solution. It was shown that the manufacture of a sugar conforming to the "factor of safety" depends upon graining it from a sirup of such purity that the surrounding medium of molasses exceeds in density the maximum at which mold fungi can develop. Molasses in the form of a film deteriorates when apparently insusceptible to such changes in deep layers. The size of grain has considerable influence upon moisture absorption, the latter varying inversely with the size, and the largest amount is absorbed the first day. The smaller grains are much more hygroscopic than the larger ones. The presence of small amounts of invert sugars and the merest traces of the decomposition products of lime upon the reducing sugars greatly increase the affinity of sugar for moisture.

In attempts to make sirup from sweet corn stalks, the Minnesota station found it possible to secure by the open kettle process about 20 gallons of excellent sirup from the stalks cut from 1 acre.

EXPERIMENT STATION WORK ON THE FAT-SOLUBLE VITAMINS

By Sybil L. Smith, *Specialist in Biological and Food Chemistry*

REVIEW OF EARLIER WORK

In the 10 years which have elapsed since the announcement almost simultaneously by the Connecticut (*1*)[1] and the Wisconsin (*2*) stations of the discovery of the presence in certain natural food materials of a fat-soluble vitamin essential to normal growth and well-being, many investigations have been conducted at various experiment stations and elsewhere, showing with ever-increasing significance the important part which the fat-soluble vitamin, vitamin A, plays in normal nutrition.

Occurrence and properties.—Following the discovery of this vitamin much information was contributed from both the Connecticut and Wisconsin stations which showed its wide occurrence in animal and vegetable materials and threw light on its physical, chemical, and physiological properties. Significant among the early contributions was the observation first reported by Osborne and Mendel (*3*) of the relation between lack of vitamin A and the development in experimental rats of a characteristic form of ophthalmia. That this was not characteristic of rats alone was shown by experiments at the Iowa station (*4*) with rabbits and at the Wisconsin station (*5*) with dogs. Evidence of more extended physiological disturbances, including general cutaneous malnutrition and a tendency toward respiratory infection, was contributed from the Wisconsin station (*6*).

Steenbock, of the Wisconsin station, developed his interesting hypothesis of a correlation between the occurrence of vitamin A and lipochrome pigment in many materials. Although this theory has been refuted by Palmer and his associates at the Minnesota station, the list of materials rich in vitamin A and in lipochrome pigment is sufficiently long and the exceptions are so few as to point to some chemical or biological relationship.

Storage.—The ability of the animal body to store fat-soluble vitamin was suggested in the earliest work of Osborne and Mendel, but failure on the part of many investigators to appreciate the effect of such storage in experimental animals has rendered valueless much of the earlier work on its quantitative occurrence.

Relation to reproduction.—It was soon discovered that this vitamin is necessary for reproduction and successful lactation, and it was realized that the experimental work should be carried through several generations. The relation of fat-soluble vitamin to reproduction has, however, been somewhat complicated by the studies of Evans and Bishop at the University of California. Briefly stated, these investigators have demonstrated two forms of sterility in rats apparently resulting from lack of unidentified constituents of the diet. One form

[1] Italic numbers in parentheses refer to References, p. 86.

(*7*) occurs on diets lacking in vitamin A in the sense in which the term is ordinarily used. This type of sterility has been definitely traced to the impairment of germ cell vigor by selective ovarian disorder. The other (*8*) has been demonstrated to occur to a considerable extent in the first generation and wholly in the second on diets consisting of purified protein, fat, and carbohydrate, with adequate amounts of vitamins A and B. This form of sterility is characterized by placental rather than ovarian disorder, and can be prevented or cured by the addition to the diet of certain foodstuffs such as fresh green lettuce leaves, alfalfa, wheat germ, and butterfat (the latter if fed in large amounts). It will be noted that all these substances contain vitamin A, but cod liver oil, which is rich in this vitamin, is ineffective in curing or preventing this form of reproductive disorder. Apparently this new vitamin, vitamin X, is closely related to but not indentical with vitamin A.

Relation to mineral metabolism.—In 1920 the Wisconsin station (*9*) reported the results of some preliminary experiments which suggested the presence in green plant tissues of a factor influencing calcium metabolism. Milking goats were brought to a negative calcium balance on a ration of air-dried grains and air-dried roughage, but when the latter was replaced by fresh material equivalent in dry matter and calcium content the negative balance was greatly reduced. The suggestion was made at this time that "under the extra strain of rapid growth or milk production not enough calcium can be assimilated for the liberal uses made of this element unless there is present an abundance of calcium in the diet, as well as an abundance of this something that assists calcium assimilation. Possibly we are dealing with the antirachitic vitamin assumed as the fourth accessory factor."

Further evidence of the correctness of this hypothesis was furnished by a more elaborately planned experiment (*10*) in which it was shown that the negative calcium balances in milking goats on dry rations could be greatly reduced by fresh green material (oats) or by the same material freshly dried or made into hay in the diffused light of an attic. Orange juice and cabbage (rich in vitamin C) and butter (rich in vitamin A) were ineffective, while cod liver oil in doses of from 5 to 10 cubic centimeters daily consistently changed the negative balance to positive. These results pointed to the identity of the vitamin assisting calcium metabolism with the antirachitic vitamin now being differentiated from vitamin A, and also emphasized the interrelationship between this type of fat-soluble vitamin and mineral metabolism.

Meaning of term "fat-soluble vitamins."—Thus the conception of the fat-soluble vitamin has enlarged to include tentatively a factor essential to growth and reproduction and to resistance to infection of various kinds, a factor intimately concerned in the metabolism of calcium and phosphorus and thus in the prevention of rickets, and possibly a factor the lack of which is responsible for sterility of a certain type. This has resulted in a confusion of terms which makes the literature on the subject somewhat difficult to interpret. The term "fat-soluble vitamin" or "vitamins" is generally used to designate the group as a whole. Vitamin A is sometimes used in the collective sense and sometimes only as representing the growth-promoting or antixerophthalmic factor. The term antirachitic vitamin refers specifically to the factor associated with the metabolism of calcium

and phosphorus, and the factor associated with reproductive disorders not due to lack of vitamin A is known as vitamin X.

WORK IN 1922

Vitamin A requirements of different kinds of animals.—Hesitancy in applying to other animals the conclusions drawn from the results obtained with the white rat, used so extensively in nutrition experiments on account of its rapid growth and small food requirements, has been largely overcome through the similarity in results obtained in vitamin work with animals of different species.

In experiments at the Iowa station (*11*) it was found that on a diet deficient but not absolutely lacking in vitamin A (white corn 55, linseed meal 22, ground oats 15, tankage 15, and salt mixture 3 parts), rabbits varying in age from 3 to 8 weeks developed ophthalmia in from 2 to 8 weeks, and died in from 2 to 3 months. On the same diet young rats grew at less than the normal rate to maturity and reproduced, but the young were not suckled and died in a few hours. A sow fed the same ration during the gestation and suckling period farrowed four unthrifty pigs, one of which died and the others grew very slowly until the ration was supplemented with butterfat. In preliminary experiments with chickens on this diet, soreness of the eyes developed in one case. These results indicate the need of vitamin A in varying amounts by all of the animals tested. That an amount sufficient for ordinary purposes may not be enough to meet the extra demands of lactation has also been demonstrated in an extension of the work with rabbits.

Evidence that the antixerophthalmic and antirachitic vitamins are not the same is furnished in experiments at the Wisconsin station on dogs (*12*). It was found impossible to prevent rickets in rapidly growing dogs with as much as 60 grams of green alfalfa or 42 cubic centimeters of orange juice as the sole source of fat-soluble vitamin, although these amounts were much in excess of those required to prevent ophthalmia. In these experiments it was shown, however, that the antirachitic vitamin resembles vitamin A in its resistance to saponification.

Chickens.—In investigations at the Wisconsin station (*13*) it was found that leg weakness developing in chickens on a synthetic diet or on a simple diet of white corn and skim milk, with a small amount of calcium carbonate and common salt, can be prevented by the use of a liberal amount of cod liver oil. When the oil was omitted from the ration the chickens died in from four to six weeks with gross symptoms of leg weakness, thus indicating that the antirachitic factor was the one chiefly involved.

The Wisconsin station (*14*) has also shown that a ration of white corn, middlings, and skim milk, previously found to be inadequate for normal growth, may be made adequate by the addition of one egg per day to the ration of 30 chicks. Growth on yellow corn, middlings, and skim milk was also improved by this addition. Furthermore, egg can be used to replace milk when the latter is not available and apparently gives as good results as a supplement of green feed. It would seem that the effect of the egg is due, in considerable measure at least, to the high content of fat-soluble vitamin in the yolk. In this connection it should be noted that egg yolk has recently

105313—24——6

been reported to be high in antirachitic vitamin (*15*, *16*). At the Wisconsin station it has been demonstrated (*17*) that the hatchability of eggs can be increase by the addition to the ration of laying hens of substances rich in vitamin A. The average hatch was higher on yellow corn and casein than on white corn and casein, and was increased in both cases by the addition of skim milk, and still more by pork liver. The low hatchability on the deficient rations was more pronounced during the latter part of the hatching season. This indicates a gradually diminishing store of vitamin A in the body of the hens, and points to the advisability of furnishing additional sources of vitamin A to hens in the late winter or early spring.

The results obtained at the West Virginia station (*18*) in a two-year study of the effect of confinement and green feeds on the number, fertility, and hatchability of eggs point indirectly to a favorable influence of vitamin A on the fertility and hatchability, but not on the number of eggs produced.

The work reported by the various stations would thus seem to indicate that the chick requires fat-soluble vitamin for growth, for successful reproduction, and for the prevention of rickets or leg weakness. Other problems of interest, some of which are under active investigation, are the most economical sources of fat-soluble vitamin for growing chickens and laying hens, a further study of the relation of feed to the hatchability of eggs to determine whether vitamin A or the vitamin X of Evans and Bishop is alone involved, and an application to chickens of the results obtained in experimental rickets in rats to determine whether lack of antirachitic vitamin can be compensated by more favorable proportions of calcium and phosphorus or by light. From the standpoint of human nutrition the selection of rations for laying hens to increase as far as possible the content of fat-soluble vitamin in the egg is of great importance.

Swine.—The problem of meeting the fat-soluble vitamin requirement of swine has been considered in studies of the comparative feeding value of yellow and white corn. The higher content of vitamin A in yellow corn, as demonstrated at the Wisconsin station (*19*), makes it especially desirable to use yellow corn in preference to white at the time of greatest need for vitamin A, or to supplement the white corn at such a time with materials rich in vitamin A.

At the Illinois station (*20*) it was found that continued subsistence on a white corn and tankage ration gradually undermined the reproductive powers of breeding sows. One sow restricted to such a ration produced litters of dead pigs in the third and fourth gestation periods. In similar feeding tests conducted on young pigs from 50 to 70 pounds in weight at the beginning of the experiment, the gains in weight and general condition of the animals receiving yellow corn were somewhat better than of those receiving white corn; and it was concluded that growing pigs require vitamin A, but that the requirement is of a low order compared with that of the reproduction period.

Experiments at the Iowa station (*21*) also indicate that for swine the difference between yellow and white corn is not so important during the later growing and fattening period as during the breeding and early growing period; that is, for the normal growth of young pigs and for successful reproduction white corn must be supplemented with good pasture or with feeds furnishing vitamin A, while for fat-

tening pigs in dry lot white corn appears to be about as efficient as yellow. Similar conclusions have been reached at the Wisconsin station (*22*), where it was found that there was a more striking difference in the rate of gain of pigs fed yellow corn and skim milk as compared with those fed white corn and skim milk in the young animals than in those which were fairly well grown at the beginning of the experiment. This was attributed to the fact that these animals had been raised on excellent rations, with good pasture, and had evidently stored sufficient vitamin A to carry them through the fattening period. Most of the young animals on the white corn ration developed rickets, as indicated by the gross symptoms and the low content of inorganic phosphorus in the blood, and also by the fact that 10 cubic centimeters of cod liver oil daily never failed to correct the deficiency. Chopped alfalfa to the extent of 5 per cent of the ration has been found by this station to be adequate to prevent rickets or paralysis in young pigs fed white corn and skim milk. It is thought probable that chopped clover or soy-bean hay would serve the same purpose equally well.

The Ohio station (*23*) has also reported that lameness, rickets, or partial paralysis in hogs can be prevented by feeding bright leafy alfalfa hay to the extent of from 3 to 5 per cent of the ration or by the addition of a mineral mixture containing steamed bone meal, ground limestone, acid phosphate, and common salt.

Dairy cattle, with special reference to mineral metabolism.—The successful feeding of dairy cattle depends largely upon the selection of such food materials as shall make for quality and quantity of milk production with as small a drain as possible upon the body reserves, particularly of calcium and phosphorus. Evidence obtained with small laboratory animals that lactation involves an increased requirement of fat-soluble vitamin and that the content of vitamin A in the milk depends upon the richness in this vitamin of the food of the lactating animal has been confirmed in an investigation at the Minnesota station (*24*) of the content of vitamins A and B in the milk of cows on rations rich and poor in these vitamins, as demonstrated by experiments with rats.

These investigations demonstrated conclusively that the content of vitamins A and B in cow's milk depends ultimately upon their presence in the ration, although storage of vitamin A in the body tissues enables the cow to maintain the level of vitamin A in the milk for some time after the supply in the feed has been exhausted. That a vitamin-rich milk is not necessarily correlated with access to pasturage was shown by the excellent results obtained with the milk from cows stall-fed on a ration of grains supplemented with alfalfa and corn silage. Such a ration would tend to furnish a more even vitamin content than a grain ration of low vitamin content supplemented by pasturage under varying climatic conditions. The drying of the pasture during a portion of the experimental period was reflected in a lowering of the vitamin content of the milk, particularly with respect to vitamin B.

In similar feeding experiments at the Ohio station (*25*) it was found that rats receiving, in addition to a basal diet free from vitamins, milk produced by cows on pasture grew faster than those receiving an equal amount of milk from cows on a dry feed. It was

suggested that the vitamins of the hay are destroyed by excessive sunlight and drying and possibly by overmaturity of the grass when cut for hay.

It is evident that the antirachitic factor is an important one to be considered in the feeding of dairy cattle if the results of the extensive investigations of the past two or three years on experimental rickets in rats are applicable to the larger animals. These have shown that the presence of the antirachitic vitamin in the food enables the animal to utilize calcium and phosphorus more efficiently.

It has long been known that lactation results in a considerable depletion of the reserve supplies of calcium, and that during this period it is very difficult if not impossible to maintain a positive calcium balance. Circumstances in which this depletion of calcium plays an important rôle are summarized by Forbes and others as follows (*26*):

> There is greater difficulty in getting a cow with calf after heavy and prolonged lactation than if bred comparatively soon after calving; cows bred too young tend strongly to remain permanently small; occasionally a cow will fail, unaccountably, after calving to approach her normal milk production; cows calving while in especially thin condition, or calving without having had an adequate dry resting period, are apt to begin lactation at less than the normal rate, or, after a brief term of production, to fail abruptly; and performance tests of milch cows, under conditions of forced production, have resulted in the loss of breeding capacity of so many superior cows as to occasion frequent comment and discussion among dairy cattle breeders.

These observations led to a series of studies at the Ohio station on the mineral and nitrogen metabolism of milch cows. In the first of these studies (*27*) it was shown that during the period of liberal milk production it was impossible to maintain a positive calcium balance on rations of hay, grain, and silage. The phosphorus balance was also negative in nearly all cases. The losses were greater on timothy than on clover hay, but the differences were not proportional to the difference in the calcium content of the two roughages. In the second series of studies (*28*) it was demonstrated that on the addition to the ration of large amounts of calcium carbonate, steamed bone flour, and sodium chlorid, the calcium balance remained negative while the phosphorus became positive; and in the third that the more soluble calcium compounds, calcium lactate and chlorid, and precipitated bone phosphate were utilized no better than the less soluble calcium carbonate.

In the fourth series of studies (*26*, *29*) the scope of the investigation was extended still further to include the whole of the productive life of the cow. In 7 of the 18 balance experiments included in the series the cows were entirely dry, in 4 were giving less than 10 pounds, and in the remaining 7 from 37.87 to 61.36 pounds of milk per day. The ration consisted of corn meal, 13 parts; cottonseed meal, linseed meal, and wheat bran, 1 part each; alfalfa hay ad libitum; and common salt in the proportion of 0.007 that of the grain. The mineral supplement consisted of equal parts of precipitated bone phosphate and precipitated calcium carbonate. As in the previous trials, the cows giving a liberal amount of milk had negative calcium balances. In contrast with this the dry cows and those giving a very small amount of milk had positive calcium balances. The phosphorus balances, with one exception, ran parallel with the calcium.

The general conclusion drawn from this series of studies was that a negative calcium balance during lactation, at least on winter rations, is practically inevitable, and that consequently it is necessary for dairy cattle to have a dry resting period during which the feeding should be sufficiently liberal for the building up of extensive reserves for the following period of lactation.

That a positive calcium balance can be obtained in lactating animals even on winter rations has been demonstrated at the Wisconsin station. Previous work with goats has been mentioned in which it was shown that a negative calcium balance may be reduced or even made positive by supplementing the dry feed with such substances as green alfalfa and cod liver oil. The negative results with fresh cabbage as a supplement have been confirmed (*30*), and similar negative results have been obtained with yellow carrots; but an alcoholic extract of alfalfa has been shown to be effective in bringing about a positive balance.

In a continuation of this investigation (*31*) an attempt was made to determime the comparative efficiency of dry and green alfalfa in maintaining calcium and phosphorus equilibrium in milking cows. It was anticipated that negative calcium balances would be obtained with dry alfalfa hay and that these would be changed to positive if the alfalfa were fed fresh and green, but in the first trial positive balances were established on both dry alfalfa hay and fresh green alfalfa. There was, however, a more liberal storage of calcium on the fresh than on the dry alfalfa. Positive phosphorus balances were also obtained. The hay used in this experiment had been cured under caps and was of excellent quality. The authors concluded that "apparently the question whether positive or negative calcium balances will prevail in liberally milking cows through the use of such an efficient carrier of calcium as alfalfa hay is determined by the quality of the alfalfa hay used. By the term quality, used in this connection, we mean the relative degree of destruction in the curing processes of the unknown factors affecting calcium assimilation."

This conclusion was confirmed in other studies (*32*) in which negative calcium and phosphorus balances were obtained in milch cows reiving alfalfa hay which had been cured in the windrow, with exposure to air and light for four days. This difference was attributed to differences in the degree of destruction during the curing process of the vitamin which assists calcium assimilation. When timothy hay was used in place of alfalfa the negative balances were higher than in the alfalfa period. Supplementing the timothy hay with bone meal did not result in calcium equilibrium.

This line of investigation appears to open up a wide field of research and of practical application. Granting the importance in animal feeding of the antirachitic vitamin, or the vitamin assisting in calcium assimilation, advantage may be taken of the results already obtained in the study of experimental rickets to study the same problems in connection with the feeding of domestic animals; to determine, for instance, whether, as has been demonstrated in rats and children, light exerts the same effect as the antirachitic vitamin, to establish more completely the content of this vitamin in various green feeds, to develop better methods of drying and keeping such feeds as are

found to contain it, and to determine the most effective time to establish, by means of properly selected rations, the calcium and phosphorus reserves of farm animals, particularly dairy cattle.

GENERAL STATUS OF INVESTIGATION

The similarity in vitamin requirements of laboratory and larger animals has been sufficiently well established to make it safe in general to take advantage of the extensive and rapidly accumulating literature on vitamins in their relation to human nutrition and to apply the established principles to animal nutrition. The importance in normal nutrition of the fat-soluble vitamin has been definitely established, but is not yet fully appreciated. There is still considerable confusion concerning the identity, occurrence, and specific functions of the various factors included in the term, and the clearing up of this confusion by a more definite separation and examination of the fat-soluble vitamins will do much to simplify the problem of correct and efficient animal feeding.

REFERENCES

(1) The relation of growth to the chemical constituents of the diet. T. B. Osborne and L. B. Mendel. Jour. Biol. Chem., 15 (1913), p. 311.
(2) The necessity of certain lipins in the diet during growth. E. V. McCollum and N. Davis. Jour. Biol. Chem., 15 (1913), p. 167.
(3) The influence of butter fat on growth. T. B. Osborne and L. B. Mendel. Jour. Biol. Chem., 16 (1913), p. 423.
(4) The effect of vatamin deficiency on various species of animals.—I, The production of xerophthalmia in the rabbit. V. E. Nelson and A. R. Lamb. Amer. Jour. Physiol., 51 (1920), p. 530.
(5) Fat-soluble vitamin.—IX, The incidence of an ophthalmic reaction in dogs fed a fat-soluble vitamin deficient diet. H. Steenbock, E. M. Nelson, and E. B. Hart. Amer. Jour. Physiol., 58 (1921), p. 14.
(6) Fat-soluble vitamin.—VII, The fat-soluble vitamin and yellow pigmentation in animal fats, with some observations on its stability to saponification. H. Steenbock, M. T. Sell, and M. V. Buell. Jour. Biol. Chem., 47 (1921), p. 89.
(7) On an invariable and characteristic disturbance of reproductive function in animals reared on a diet poor in fat-soluble vitamin A. H. M. Evans and K. S. Bishop. Anat. Rec., 23 (1922), p. 17.
(8) On the existence of a hitherto unrecognized dietary factor essential for reproduction. H. M. Evans and K. S. Bishop. Science, 56 (1922), p. 650. Amer. Jour. Physiol., 63 (1922), p. 396.
(9) The influence of dry v. fresh green plant tissue on calcium assimilation. E. B. Hart, H. Steenbock, and C. A. Hoppert. Science, 52 (1920), p. 318.
(10) Dietary factors influencing calcium assimilation.—I, The comparative influence of green and dried plant tissue, cabbage, orange juice, and cod liver oil on calcium assimilation. E. B. Hart, H. Steenbock, and C. A. Hoppert. Jour. Biol. Chem., 48 (1921), p. 33.
(11) The effect of vitamin deficiency on various species of animals. V. E. Nelson, A. R. Lamb, and V. G. Heller. II, Observations on the comparative vitamin A requirement of rabbits, rats, swine, and chickens. Amer. Jour. Physiol. 59 (1922), p. 335. III, The production and cure of xerophthalmia in the suckling. Amer. Jour. Diseases Children, 23 (1922), p. 518.
(12) Wisconsin Sta. Bul. 352 (Report of Director, 1922), p. 16. 1923.
(13) The nutritional requirements of baby chicks.—II, Further study of leg weakness in chickens. E. B. Hart, J. G. Halpin, and H. Steenbock. Jour. Biol. Chem., 52 (1922), p. 379.
(14) Wisconsin Sta. Bul. 352 (Report of Director, 1922), p. 7. 1923.
(15) The therapeutic value of egg yolk in rickets. A. F. Hess. Jour. Amer. Med. Assoc., 81 (1923), p. 15.
(16) The antirachitic influence of egg yolk. H. Casparis, P. G. Shipley, and B. Kramer. Jour. Amer. Med. Assoc., 81 (1923), p. 818.

(17) Wisconsin Sta. Bul. 352 (Report of Director, 1922), p. 9. 1923.
(18) Effect of confinement and green feed on number and hatchability of eggs. H. Atwood. West Virginia Sta. Bul. 178. 1922.
(19) Fat-soluble vitamin.—III, The comparative value of white and yellow maizes. H. Steenbock and P. W. Boutwell. Jour. Biol. Chem., 41 (1920), p. 81.
(20) Illinois Sta. Rpt. 1922, p. 16.
(21) Iowa Sta. Rpt. 1922, p. 37.
(22) Wisconsin Sta. Bul. 352 (Report of Director, 1922), p. 19. 1923.
(23) Ohio Sta. Bul. 362 (Rpt. 1922), p. XLVIII.
(24) Vitamin studies.—IX, The influence of the diet of the cow upon the quantity of vitamins A and B in the milk. C. Kennedy and R. A. Dutcher. Jour. Biol. Chem., 50 (1922), p. 339.
(25) Ohio Sta. Bul. 362 (Rpt. 1922), p. XLVI.
(26) The mineral metabolism of the milch cow. E. B. Forbes, J. A. Schulz, C. H. Hunt, A. R. Winter, and R. F. Remler. Jour. Biol. Chem., 52 (1922), p. 281.
(27) The mineral metabolism of the milch cow. First paper. E. B. Forbes, F. M. Beegle, et al. Ohio Sta. Bul. 295. 1916.
(28) The mineral metabolism of the milch cow. Second paper. E. B. Forbes, F. M. Beegle, et al. Ohio Sta. Bul. 308. 1917.
(29) The mineral metabolism of the milch cow. E. B. Forbes, C. H. Hunt, J. A. Schulz, A. R. Winter, and R. F. Remler. Ohio Sta. Bul. 363. 1922.
(30) Wisconsin Sta.Bul. 352 (Report of Director, 1922), p. 16.
(31) Dietary factors influencing calcium assimilation.—II, The comparative efficiency of dry and green alfalfa in maintaining calcium and phosphorus equilibrium in milking cows. E. B. Hart, H. Steenbock, and C. A. Hoppert. Jour. Biol. Chem., 53 (1922), p. 21.
(32) Dietary factors influencing calcium assimilation.—III, The comparative efficiency of timothy hay, alfalfa hay, and timothy hay plus calcium phosphate (steamed bone meal) in maintaining calcium and phosphorus equilibrium in milking cows. E. B. Hart, H. Steenbock, C. A. Hoppert, R. M. Bethke, G. C. Humphrey. Jour. Biol. Chem., 54 (1922), p. 75.

STATION INVESTIGATIONS ON FRUIT-BUD FORMATION

By J. W. Wellington, *Specialist in Horticulture*

The fact that profitable fruit production is primarily dependent upon the development of an adequate supply of flower buds renders the knowledge of the factors directly affecting such formation of immediate concern to the horticulturist. Nevertheless, the attainment of exact knowledge has been relatively slow, and only since investigators have begun to use the more exact methods of plant cytology, chemistry, and biometrics has real progress been evident. The early horticulturist knew from changes in the outward form that flower buds of certain fruits were differentiated in the season preceding blossoming; it remained for the investigator to determine the exact time the process occurs and the factors involved.

Fruit-bud differentiation.—The Wisconsin station (*40, 41, 43*)[2] was the first of the American stations to study the exact time of differentiation in fruits. This original work was remarkable, not only for the large number of species studied, but also for the accuracy of the deductions arrived at. It was concluded that the fruit bud is not essentially different from the leaf bud, but that differentiation is primarily dependent upon internal nutritional conditions at the time of cessation of vegetative growth. The recommendation made at this time, following the discovery that strawberry blossoms are differentiated in the fall, namely, that beds should receive better care in the autumn, accords with the conclusions reached many years later by the Missouri station (*14*).

Among other stations to contribute knowledge concerning the time of fruit-bud differentiation are Georgia (*3*), Virginia (*34*), Oregon (*26, 27, 28*), New Hampshire (*17*), and Iowa (*5*).

Effect of fertilizers.—The rôle that fertilizers play in stimulating fruit-bud formation has long been a subject of earnest inquiry, and many conflicting ideas have been advanced. The work of the New York State station (*23*), New Hampshire station (*15*), and Pennsylvania station (*32*) has shown that trees growing in naturally fertile soils under good cultural conditions do not respond in yield to fertilizers. On the other hand, the Oregon station (*31*) found that nitrate of soda not only stimulated the number of spurs to blossom, but also increased the percentage of fruit to set, and as a result increased the yield.

In short-lived and rapid-growing trees, such as the peach, it has been generally conceded that on relatively poor soils nitrogen fertilizers are highly essential; the West Virginia station (*37*), for example, noted that nitrate of soda greatly increased the number of fruit buds on peach trees. The Wisconsin station (*38*) found a definite correlation between the annual increase in length of Wealthy

[2] Italic numbers in parentheses refer to References, p. 92.

apple spurs and their blossom bud performance, the maximum production of buds being found to be correlated with spurs of moderate growth. This finding was later corroborated by the Iowa station (*6*), the Missouri station (*12*), and by the Illinois station (*4*). From these observations it is evident, therefore, that in orchards where nitrogen is a limiting factor in growth, fruit-bud formation being primarily dependent upon an adequate vegetative growth of the tree is in turn influenced by nitrogen applications.

The Missouri station (*13*) found that the time of application of nitrogen fertilizers is a very important consideration and recommended that fertilization should conform with the fruiting performance of the tree. On the other hand, potash and phosphoric acid have shown little value for orchard trees except as they stimulate the cover crop growth, which in turn affects the tree development. The significance of fertility practices in relation to fruit-bud formation was greatly clarified by the hypothesis advanced by the Oregon station (*29*); namely, that fruitfulness in a plant depends primarily upon a satisfactory balance between nitrogen and carbohydrate contents. Much of the intense interest recently manifested by the station workers in fruit-bud performance may be directly traced to this fundamental contribution.

Effect of soil treatment.—That soil management has a material effect on fruit-bud formation was noted by the New York State station (*22*) which reports that trees in tillage were much more productive than those in sod. The New Hampshire station (*16*) found that Baldwin trees in tillage and those in tillage plus cover crops were more productive of fruit buds in the off season than were trees in sod. This fact was also noted by the Iowa station (*7*) and the Virginia station (*35*). The Oklahoma station (*25*) found that mulching with straw tended to increase fruit-bud formation in the peach and in the cherry. The Wisconsin station (*44*) found in supplying water during a drought to one of a pair of Gideon apple trees that an abundant water supply had no stimulating effect upon fruit-bud development, either in respect to time of differentiation or in percentage of fruit buds formed.

Effect of pruning, defoliation, and girdling.—The effect of pruning upon fruit-bud formation has been studied by many of the stations. At the Virginia station (*33*) it was found that spring pruning of dwarf apple trees tended to discourage, summer pruning to encourage, and fall pruning to have little effect upon fruit-bud formation. The California station (*1*) noted that lightly pruned fruit and nut trees came into bearing from one to three years earlier than did similar severely pruned trees. The deleterious effect of severe pruning upon immature trees has also been studied by the New York Cornell station (*21*), the New York State station (*24*), the New Jersey stations (*20*), the Massachusetts station (*8*), and the California station (*2*).

At the Wisconsin station (*38*) it was found that the biennial bearing tendency in the Wealthy apple could be partly overcome by moderate pruning in the off-bearing year. At the same station (*42*) it was observed that partial defoliation of pear spurs hastened fruit-bud formation. The Oregon station (*30*) reported that defoliation of spurs early in the season strongly hindered fruit-bud formation in 7-year-old apple trees, and concluded that the apple spur possesses individuality in a high degree. The Missouri station (*12*), completing a biometrical study of the bearing habit in annual and

biennial fruiting apple trees, concludes that the factors influencing spur performance are localized narrowly at times, widely at others, and that in all cases studies of the factors determining fruit-bud differentiation should not be confined to the spur alone.

Studies with American plums at the Wisconsin station (*39*) indicated that early defoliation may cause an entire absence of fruit-bud formation, but that later defoliation may have little or no inhibitory effect. The Massachussetts station (*9*) found that girdling stimulated fruit-bud formation in 7-year-old apple trees carrying little or no fruit, whereas the same treatment had no effect on more productive trees.

Effect of light.—Studies upon the effect of light on fruit-bud formation have been reported from the New Hampshire station (*18*) and the Wisconsin station (*46*) and in general have shown that the reduction of light during the growing season results in the practical elimination of fruit-bud development. The New Hampshire station (*19*) asserts that the cessation of fruit-bud formation beneath shade is due either to a reduction in carbon assimilation or an increase in nitrogen intake, or perhaps to a combination of both of these causes.

Chemical studies.—As has been previously indicated, chemical studies of various kinds have materially contributed to the advance in knowledge of fruit buds and their development. The work of the Oregon station (*29*), already mentioned, has been followed by contributions from other stations upon the same general subject. The Missouri station (*10*), studying factors promoting fruitfulness and nonfruitfulness in apple spurs, reported sugar and starches to be slightly more abundant in productive than in nonproductive spurs, and at the same time noted that apple spurs are most productive between the ages of 3 and 7 years. The Oregon station (*30*) found that defoliation of apple spurs modified their chemical composition, resulting in a sharp increase in nitrogen constituents and a decrease in carbohydrates. The Wisconsin station (*45*) reports that blossom-bud formation occurred most abundantly in apple trees which contained an intermediate percentage of nitrogen and the reciprocal condition of an intermediate percentage of carbohydrates.

Analyses reported by the New Hampshire station (*19*) of the last two years' growth of two alternate bearing apple trees fruiting in different years showed fruiting trees to be slightly higher in moisture and in total nitrogen. Investigations at the Virginia station (*36*) indicated that early spring applications of nitrate of soda were more effective in promoting growth and yield than were later applications. Determinations by the Missouri station (*11*) upon the chemical contents of apple spurs collected at intervals during the year showed seasonal changes in composition distinct and characteristic of the condition of the spur in relation to productivity. Conditions leading to high starch and low nitrogen conditions at the time of fruit-bud differentiation were found essential to productivity.

Summary.—Experimental activities relating to the underlying causes of fruit-bud formation date back to only about the beginning of the present century; and although much knowledge has been acquired in this brief period concerning the time of differentiation of flower buds in various fruits, only an inkling has been obtained concerning the nutritive conditions associated with such formation. Progress in the latter subject is largely due to the lucid theory elab-

orated by Kraus and Kraybill; namely, that fruitfulness is dependent upon a satisfactory balance between the nitrogen and carbohydrate contents of the plant itself. Formation of flower buds is dependent upon an accumulation of carbohydrates above that required for purely vegetative development. On the other hand, an excess of nitrogen leads to a rapid utilization of carbohydrates, thus preventing their accumulation. Present knowledge, though meager, is sufficient for the formulation of rational plans for pruning, fertilization, and cultivation based on the actual needs of the tree rather than on empirical results of practice. Maximum production of fruit buds is apparently correlated with vigorous but not excessive vegetative growth.

In the light of present knowledge, it is highly possible that one of the serious problems besetting fruit growers, namely, that of overcoming the tendency of many important apple and pear varieties to fruit biennially, may be solved. Again, the tendency for fruit trees to overbear, with the consequent necessity of thinning the fruits or supporting the limbs, may be partially overcome by more enlightened practices of fertilization and pruning. In view of the active interest that many of the stations are now taking in fruit-bud studies, there is every reason to look forward to valuable progress in the near future.

REFERENCES

(1) Pruning young deciduous fruit trees. W. P. Tufts. California Sta. Bul. 313. 1919.
(2) Pruning young olive trees. F. T. Bioletti. California Sta. Bul. 348. 1922.
(3) Georgia Sta. Rpt. 1900, p. 350.
(4) The effect of certain potassium and nitrogen fertilizers on the shoot growth and flower formation of the peach. W. A. Ruth. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 152–160.
(5) A study of the formation and development of the flower buds of Jonathan and Grimes Golden in relation to different types (clover sod, blue-grass sod, cover crop, and clean tillage) of soil management. R. S. Kirby. Iowa Acad. Sci. Proc., 25 (1918), pp. 265–287.
(6) Factors which influence the production and growth of fruit buds on the apple. T. J. Maney and H. H. Plagge. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 100–103.
(7) Fruit bud production in the apple. T. J. Maney and H. H. Plagge. Amer. Soc. Hort. Sci. Proc., 17 (1920), pp. 250–256.
(8) Recent developments in the practice and principles of pruning. J. K. Shaw. Vt. State Hort. Soc. Ann. Rpt., 18 (1920), pp. 24–31.
(9) An experiment in ringing apple trees. J. K. Shaw. Amer. Soc. Hort. Sci. Proc., 19 (1922), pp. 216–220.
(10) Some factors favoring or opposing fruitfulness in apples.—The effect of certain conditions and practices on the development and performance of the individual fruit spur. C. C. Wiggans. Missouri Sta. Research Bul. 32. 1918.
(11) Seasonal changes in the chemical composition of apple spurs. H. D. Hooker, jr. Missouri Sta. Research Bul. 40. 1920.
(12) Localization of the factors determining fruit bud formation. H. D. Hooker, jr., and F. C. Bradford. Missouri Sta. Research Bul. 47. 1921.
(13) Certain responses of apple trees to nitrogen applications of different kinds and at different seasons. H. D. Hooker, jr. Missouri Sta. Research Bul. 50. 1922.
(14) Studies in the nutrition of the strawberry. V. R. Gardner. Missouri Sta. Research Bul. 57. 1923.
(15) The effects of fertilizers in a cultivated orchard. J. H. Gourley. New Hampshire Sta. Bul. 168. 1914.
(16) Studies in fruit-bud formation. J. H. Gourley. New Hampshire Sta. Tech. Bul. 9. 1915.
(17) The nature of the inflorescence and fruit of *Pyrus malus*. C. A. Black. New Hampshire Sta. Tech. Bul. 10. 1916.

(18) The effects of shading some horticultural plants. J. H. Gourley and G. T. Nightingale. New Hampshire Sta. Tech. Bul. 18. 1921.
(19) Effect of shading and ringing upon the chemical composition of apple and peach trees. H. R. Kraybill. New Hampshire Sta. Tech. Bul. 23. 1923.
(20) Some results of pruning investigations with peaches. M. A. Blake. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 213–222.
(21) Results of some experiments in pruning fruit trees. W. H. Chandler. New York Cornell Sta. Bul. 415. 1923.
(22) Is it necessary to fertilize an apple orchard? U. P. Hedrick. New York State Sta. Bul. 339. 1911.
(23) Twenty years of fertilizers in an apple orchard. U. P. Hedrick and R. D. Anthony. New York State Sta. Bul. 460. 1919.
(24) Growth and yield of apple trees pruned in various ways. G. H. Howe. New York State Sta. Bul. 500. 1923.
(25) Oklahoma Sta. Rpt. 1919, p. 47.
(26) The pollination of the pomaceous fruits.—I, Gross morphology of the apple. E. J. Kraus. Oregon Sta. Research Bul. 1, pt. 1. 1913.
(27) The pollination of the pomaceous fruits.—II, Fruit-bud development of the apple. F. C. Bradford. Oregon Sta. Bul. 129. 1915.
(28) The influence of summer pruning on bud development in the apple. J. R. Magness. Oregon Sta. Bul. 139, pp. 46–67. 1916.
(29) Vegetation and reproduction with special reference to the tomato. E. J. Kraus and H. R. Kraybill. Oregon Sta. Bul. 149. 1918.
(30) The relation of carbohydrates and nitrogen to the behavior of apple spurs. E. M. Harvey and A. E. Murneek. Oregon Sta. Bul. 176. 1921.
(31) The influence of nitrogen upon the vigor and production of devitalized apple trees. C. I. Lewis and R. W. Allen. Oregon Sta. Rpt. Hood River Branch Sta. 1915, pp. 5–19.
(32) Methods of interpreting yield records in apple fertilization experiments. R. D. Anthony and J. H. Waring. Pennsylvania Sta. Bul. 173. 1922.
(33) Some effects of pruning, root pruning, ringing and stripping on the formation of fruit buds on dwarf apple trees. A. W. Drinkard, jr. Virginia Sta. Tech. Bul. 5. 1915.
(34) Fruit-bud formation and development. A. W. Drinkard, jr. Virginia Sta. Rpts. 1909–10, pp. 159–205.
(35) Virginia Sta. Rpt. 1919, p. 8.
(36) Effect of time of application of nitrogenous fertilizers on tree growth, bloom and fruit production. G. S. Ralston. Amer. Soc. Hort. Sci. Proc, 18 (1921), pp. 118–123.
(37) The fertilization of peach orchards. W. H. Alderman. West Virginia Sta. Bul. 150. 1915.
(38) Off-year apple bearing and apple spur growth. R. H. Roberts. Wisconsin Sta. Bul. 317. 1920.
(39) Effect of defoliation upon blossom bud formation. R. H. Roberts. Wisconsin Sta. Research Bul. 56. 1923.
(40) The origin and early development of the flowers in the cherry, plum, apple and pear. E. S. Goff. Wisconsin Sta. Rpt. 1899, pp. 289–303.
(41) Investigation of flower buds. E. S. Goff. Wisconsin Sta. Rpt. 1900, pp. 266–285.
(42) Wisconsin Sta. Rpt. 1900, p. 280.
(43) Investigation of flower buds. E. S. Goff. Wisconsin Sta. Rpt. 1901, pp. 304–316.
(44) Wisconsin Sta. Rpt. 1901, p. 312.
(45) Nitrogen reserve in apple trees. R. H. Roberts. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 143–145.
(46) Light in relation to the growth and chemical composition of some horticultural plants. G. T. Nightingale. Amer. Soc. Hort. Sci. Proc., 19 (1922), pp. 18–29.

PROGRESS IN AGRICULTURAL ENGINEERING AT THE STATIONS

By R. W. Trullinger, *Specialist in Rural Engineering*

INTRODUCTION

Agricultural engineering has steadily progressed in recent years, first as a teaching subject, then as a service branch, and is now gradually taking its place in the field of investigation at the experiment stations. Although considerable progress has been made in providing a broad, general background, and to a certain limited extent in formulating purely agricultural engineering principles, the development of inquiry along advanced lines has been slow.

The project lists of the experiment stations show a relatively small but gradually increasing number of projects in the field of agricultural engineering. The latest of such lists includes 162 projects, distributed as follows: Land clearing 12, drainage 19, farm buildings 19, farm machinery 31, farm power 11, farm water supply and sewage disposal 9, irrigation 36, materials of construction 21, and miscellaneous 4. Twenty-eight experiment stations are represented in this work in the following States: Idaho, Wyoming, Minnesota, Oregon, Wisconsin, Alabama, Illinois, Michigan, California, Mississippi, Montana, North Carolina, Iowa, Kentucky, Indiana, Arkansas, Nebraska, New York, West Virginia, Missouri, New Jersey, Colorado, Utah, Arizona, New Mexico, Nevada, Pennsylvania, and Ohio. The experiment station on the island of Guam is also represented.

The majority of the agricultural engineering projects have until recently been rather elementary, relating to the design of structures, comparisons of farm equipment or methods, and similar subjects; but such elementary projects have proved to be very necessary in some cases in the evolution of projects of research grade. They have not only served to point out numerous lines of inquiry in which it is desirable that the underlying facts and principles be determined but have brought out the importance of planning and executing investigational work with a logical starting point and a definite aim in each instance.

FARM MACHINERY

Some of the most striking examples of investigation of a rather elementary character have occurred in the field of farm machinery.

Tractors.—Tractors of different types, sizes, shapes, and general characteristics were thrown on the market several years ago. These gradually increased in number and the State colleges and experiment stations were besieged with inquiries. This naturally led to comparative tests of one kind or another to meet immediate demands for information, and at one time national and even international tests and demonstrations of a comparative nature were held.

From these tests the necessity for more specific studies of tractor characteristics in relation to farming requirements became evident. Accepting engine and transmission characteristics and functions as purely mechanical engineering matters, several of the experiment stations began to look into operating characteristics in actual farm work. Considerable general work had, of course, been done previously by commercial concerns in the development of specific tractor types, but nothing of a very fundamental nature had been brought out.

It developed that the relation of lug equipment of drive wheels to traction is one of the most important factors in the farm-tractor problem. Numerous comparative tests of different sizes and shapes of drive-wheel equipment were conducted by both public and private institutions at considerable expense, to determine which would give the best results over a wide range of soil types. Among these, the tests at the Indiana station (*1*)[3] may be particularly mentioned. These and several other similar tests from different sources were described in some detail by R. U. Blasingame in a contribution from the Pennsylvania station (*2*). These tests indicated the complexity of the problem of traction under farming conditions, and led M. L. Nichols and J. W. Randolph, of the Alabama station, to undertake a study of the fundamental factors influencing the traction of wheel tractors, with particular reference to Alabama soils. This work resulted in the first Adams fund project ever established in this branch of agricultural engineering at a State agricultural experiment station. The first annual report of this project is in course of preparation.

It is significant to note that the main premise adopted in this project was that traction is primarily a function of soil conditions and secondarily of the design of the tractor wheel, evidently a fundamental conception. It was therefore planned to determine first what soil factors affect traction, the relation and valuation of these factors, and more specifically the lines of maximum, minimum, and intermediate resistance to traction in the soil. The next step was to determine the factors of tractor-wheel design, including materials, shape, size, location, and inclination of lugs necessary to meet the soil conditions imposed. Thus the ultimate object was to devise tractor-wheel equipment which would deliver the maximum components of impulsive force along the lines of maximum resistance in the soil.

The results to date, although far from complete, have led to the tentative conclusions that the distribution of impulsive forces in the soil can be accurately determined. The amount and efficiency of traction are increased in sand up to 8 per cent moisture content and are decreased at 16 per cent moisture content. Clay permits better traction than sand except under extreme moisture conditions. The point of greatest efficiency or permissible slip is not constant, occurring later in dry loose soils than in moist compressed soils. A close relation was established between the traction developed by a slowly rotating wheel when advancing and the force exerted by a stationary rotating wheel. A relationship was also established between traction and bearing value, resistance to penetration, and shearing strength of soils. Hardness, cohesive, adhesive, fractional, and puddling properties, tenacity, and plasticity are other soil factors which have assumed considerable importance in this work.

[3] Italic numbers in parentheses refer to references, p. 109.

The problem under such analysis has thus resolved itself primarily into one of soil dynamics and the influence thereof on traction. The failure of previous work to yield fundamental information regarding traction obviously has impressed the investigators with the importance of beginning the work with a consideration of the requirements of the thing most vitally concerned, the soil.

Tillage machinery.—Everything indicates that the more or less neglected soil factor really constitutes the logical starting point for many studies of tillage machinery and should profoundly influence their ultimate trend. For example, E. V. Collins at the Iowa station, in studies on factors influencing the draft of plows (*3, 4, 5*), showed that the type of plow bottom does not materially influence the draft, and that an increase in speed will produce about the same increase in draft with any type of bottom. The increase in draft due to speed was found to be confined to that part of the total which is required for turning and pulverizing, and varied with the speed from less than one-third to about one-half the total draft of the plow within a speed range of from 2 to 4 miles per hour. Under some plowing conditions a sharp cutting edge was of little importance, and under certain conditions high speeds caused failure to scour. These results indicate the primary importance of soil mechanics as the controlling factor.

Other plowing tests by J. B. Davidson and Collins at the Iowa station (*6*) and of a large number of plowing tests by O. W. Sjogren at the Nebraska station (*7*), by M. M. Jones at the Missouri station (*8, 9*), and by A. H. Hoffman at the California station (*10*) indicated the importance of the soil as a factor for primary consideration in studies of tillage machinery. This was also brought out in a large number of disk harrow tests by Hoffman and E. J. Stirniman at the California Station (*11*), by Sjogren at the Nebraska station (*7*), by Jones at the Missouri station (*9*), and by Collins at the Iowa station (*12, 13, 14*).

In a more fundamental study of the plow bottom and its action on the furrow slice, at the New York Cornell station (*15*), E. A. White attempted to develop a theory for the design of plow bottoms. The results, while inconclusive, gave reason to believe that there is a mathematical form to which the surface of the plow bottom should conform, in view of the fact that the soil particles follow very definite paths when passing over the surface of the moldboard. This work also pointed to the soil as the logical starting point of such investigations.

With this same thought in mind, Hoffman at the California station planned a study which was originally intended to devise a method of measuring the coefficient of static and kinetic friction between any given soil and polished metal surfaces, but which was finally reduced to a study of the factors governing static friction between the metal surfaces of farm machines moving through or over soil and different soil types.

Nichols at the Alabama station undertook to develop an even more fundamental conception of the influence of the soil factor on the operation of traction and tillage machines (*16*). He has pointed out the needs of research along the lines of soil dynamics which will be peculiarly applicable to agricultural engineering requirements. He

105313—24——7

has also shown that seed-bed preparation and cultivation, as well as traction, are processes, the efficiency of which depends upon adapting the implement to the mechanical properties of the soil.

A survey of work on tillage and tillage machinery at a number of the experiment stations and by several private commercial concerns has shown the necessity for an entirely new classification of soils and their properties with reference to the engineering aspects of tillage. With this in view, Hoffman at the California station has devised a method for measuring and standardizing the state of tilth of soil (*17*). This method involves the use of six screens of different mesh sizes, placed one above the other, the top screen having an 8-inch mesh, the next a 4-inch mesh, and so on down to the bottom screen, with a 0.25-inch mesh. The soil sample, taken to the depth of tilth in an undisturbed condition, is gently deposited upon the top screen, and the percentage by weight retained by each screen is recorded. Only the 0.5 and 0.25 inch screens are shaken. Curves platted from such data show the states of tilth in different soils and the tendencies of tillage operations in influencing tilth conditions. This method has been recommended as a standard for indicating state of tilth by the Research Committee of the American Society of Agricultural Engineers.

Air cleaning of tractor motors.—The work on air cleaning for tractor motors is another interesting instance of the evolution of research in agricultural engineering. The need for work of this character was reflected in a number of the so-called tractor surveys, which have been conducted from time to time by the experiment stations in nearly every State where tractors are used to any extent. This need seems to be especially important in some of the far Western and Southern States where extremely dusty conditions prevail during parts of the year. A large amount of work of an empirical nature has been done on this subject at great expense by manufacturers of tractor accessories and equipment, but has been limited to the development of mechanical devices.

In preliminary work at the California station (*18*), Hoffman tested 26 air cleaners for tractor motors representing all the more prominent makes and types, the purpose being to compare the dust-separating efficiency, vacuum effect, and effect on maximum possible power of the motor of the different cleaner types. These cleaners included 8 of the dry type, 9 of the water type, and 9 of the oil type. The results showed that the oil types gave the most uniformly efficient results, followed in order by the water and dry types. The effect on power of the engine was found to be negligibly small for the average of each group, but the results were not final.

In further work (*19*) Hoffman developed methods of testing dust-separating efficiency (*20*). In order that all air cleaners might have to meet the same conditions, a standard dust was made up from ten 50-pound samples of field soils taken from 10 regions in California where tractor motor wear due to dust conditions is very rapid. By a pulverizing and air floating process, the dustier portions were separated from the rest. This air-floated portion constituted 99 per cent of the standard dust used, and the other 1 per cent was a very fine sand. A small circular brush revolved by a motor swept the dust into the stream of air entering the cleaner under test, and the rate of feed was varied by use of screws of different pitches and by

varying the period of a contact pendulum which operated the screws. Although the testing methods constituted a valuable contribution, the results of the cleaner tests were apparently only of comparative value; but the experience gained indicated the importance of giving more consideration to the thing most vitally concerned, the dust itself.

Nichols at the Alabama station undertook to learn more about the fundamental scientific principles governing the dust and its movement in an air cleaner, and its consequent maximum removal from the tractor air intake within a given range of partial vacua caused by intake suction and within a given range of amount and of physical, mechanical, and chemical composition of dust. He finally arrived at the tentative conclusion that the solution of the problem rests upon the determination of the factors governing the so-called decolloidization of the dust floating or suspended in the air. His theory is that once the air-floated dust is flocculated it can be controlled and removed by known mechanical principles. Further investigations on the subject are in progress to indicate the principles which, when embodied in any air cleaner, will cause the maximum practicable dust removal under the conditions imposed.

Side draft.—Hoffman at the California station (*21*) has shown that side draft, the stumbling block in many mechanical tillage devices, is governed by the laws of mechanics that apply to forces in general, and is always in evidence if the resisting force of the implement pulls to one side instead of parallel to the direction of motion. He found that no hitch, patented or otherwise, can prevent side draft when the center lines of pull of a tractor and of resistance of an implement are offset and the hitch is to the center of a symmetrically placed drawbar, but that it can be removed by making these lines coincident.

E. A. White, in a study of equalizers and hitches at the Illinois station (*22*), evolved a mathematical method by which equalizers and hitches may be analyzed, thereby affording a means of making fundamental comparisons and when desired of predicting the results as regards side draft, especially what may be expected in a given case.

Miscellaneous machinery.—Davidson and Collins, of the Iowa station, working in cooperation with the soils department of the station, recently completed a study of limestone and fertilizer spreaders (*12, 23*). Tests of commercial limestone spreaders and a study of the various methods of handling limestone indicated requirements and desirable features of a limestone spreader which eliminated all the commercially available types. The results pointed the way to the development of an effective machine which took the form of a trailer behind a loaded wagon, using a revolving finger type of distributor. This case illustrates an effective way to proceed in such matters, in that it began with a study of what a limestone spreader should do, with special consideration of the properties of the limestone itself, passed through the stages of testing available machines and establishing the engineering principles on which an efficient machine should be constructed, and ended with the actual construction of a satisfactory machine.

F. W. Duffee, of the Wisconsin station, in elaborate tests of the relative efficiencies of 20 different silage cutters and fillers (*24*), revealed a broad variation in the power requirements of different

machines performing the same function, thus indicating that light-draft machines are more the result of perfection of design than of type. The necessity for fundamental studies of the requirements of the processes which must be met by these machines to serve as a basis for their development was thus made evident.

G. R. B. Elliott and J. L. Larson, of the Minnesota station, in their experiments on the first breaking of peat lands (*25*), found it necessary to develop special types of marsh plows. Here was a case in which studies along one line brought out the necessity of conducting studies along another line before the first studies could be completed—a not unusual occurrence in a relatively new subject such as agricultural engineering.

FARM STRUCTURES

There is a long record of work on farm buildings at the experiment stations, most of which, however, has been merely an application of well-known engineering knowledge and skill in the design of farm structures, frequently as a purely service function. Previous to the year 1922 almost every State agricultural college and experiment station engaged in some such work, but instances of serious research in this field have been rare.

Elevators.—The Iowa station was one of the first to recognize the importance of putting the studies of farm buildings on a fundamental basis. W. G. Kaiser and W. A. Foster, of that station, conducted studies of farm elevators (*26*) which brought out clearly the importance of logical starting and finishing points in farm-building studies, and also illustrated the application of engineering and purely scientific principles to such work. The studies began with a consideration of the requirements of the thing most vitally affected, the grain, and ended with the development of elevators designed to handle the grain with a maximum of efficiency.

Roofs.—Another instance worthy of mention is the work at the Iowa station by F. C. Fenton and A. W. Clyde (*27*), which was developed by Clyde into a specific study of self-supporting barn roofs (*28*). These studies dealt primarily with roofs for different types of barn. Significant conclusions from the first studies were that practically nothing definite is known of the strength of ordinary barn roofs, and that none of the common types will withstand a wind of 90 miles per hour. The results were taken to indicate the need for studies of the stength of the various types of roof with a view to evolving rational methods of design to meet the requirements of self-supporting roofs.

Tests by Clyde and H. Geise (*29*) of a masonry-arch barn roof, consisting of three reinforced concrete arch ribs filled in between with reinforced clay block, showed that the breaking load was approximately four times that produced by a 90-mile wind and that the design was much heavier than is required in practice. This would point to the necessity for a more thorough study of strength requirements of barn roofs, as a basis for design.

Silos.—A considerable amount of work on silos has been done at a number of the stations, much of which has consisted largely of comparative tests of different types of structure to suit the requirements of different materials. However, the work at the Iowa station began

with a consideration of the requirements of silage making and preservation. The early work of Davidson and M. L. King (*30*) indicated that the essentials of good silo construction require air-tight walls and doors, walls smooth inside and rigid enough to withstand the pressure of the silage, and an air space between the walls to prevent freezing. Further work by Davidson and King (*31*) resulted in the development of the silo constructed of reinforced hollow clay building blocks, which embodied nearly all the essential requirements for proper silage making and preservation. Subsequent work by Davidson (*32*) and by C. K. Shedd and W. A. Foster at the Iowa station (*33*) resulted in the further fundamental development of types adapted to special conditions, such as the wooden hoop, pit, and monolithic concrete silos.

Further studies at the Iowa station on the influence of silo wall construction on the freezing of silage (*34*) showed that during cold weather the temperature at the inside of the north wall is only a little warmer than the outside temperature for wood-stave, hollow-tile, or monolithic-concrete silos. This resulted in the conclusion that there is no practical difference between the insulating properties of the three types of construction.

In accordance with a similarly fundamental conception of the silo problem, S. I. Bechdel conducted studies at the Pennsylvania station on the preservation of corn silage (*35*) in wood-stave, concrete-block, hollow-clay-block, and monolithic-concrete silos. These indicated that maximum temperatures higher than 80° F. are not necessary, that the total acidity of silage near the center is greater than that near the walls, and that near the walls there is proportionately more acetic and less lactic acid due to less firm packing. The proportion of lactic acid developed in stave silos was higher than in the concrete types, but otherwise there were no characteristic differences in the chemical composition of the silages made in the different silos.

With these results apparently in mind, studies conducted at the Iowa station (*36*) on means of making impervious silo walls constructed of porous materials showed that the application of bituminous material to the surface, by first sizing with a solution of the bitumen and later with a hot application, most satisfactorily resisted the action of the silage and had little tendency to peel or scale off.

Studies were also conducted at the Nebraska station by L. W. Chase (*37*) on the weight and capacity requirements of silage as a basis for the design of silos for structual strength. This work was elaborated at the Kansas and Missouri stations by C. H. Eckles, O. E. Reed, and J. B. Fitch (*38, 39*) and established the fact that the weight of silage is subject to so much variation that no table of silage weights and silo capacities can be more than approximately correct. Thus the importance of further fundamental development of silos to meet economically and effectively the requirements for the proper curing and preservation of silage is plainly evident.

Ventilation.—Considerable interest has been awakened recently in the ventilation of farm buildings not only for animal shelter but for crop storage as well, and the United States Department of Agriculture and several of the stations have entered into investigations of various phases of the subject.

In a study of some of the fundamentals of stable ventilation, H. P. Armsby and M. Kriss, of the Institute of Animal Nutrition of the Pennsylvannia State College, in cooperation with the United States

Department of Agriculture (*40*), attempted to show how the results of direct determinations of the heat production of cattle and other stock may be applied to the problems of stable ventilation, and how the heat production in any specific case may be computed with a fair approximation to accuracy. The results showed that the best thermal surroundings for animals should be between a temperature somewhat above the critical point, and one not so high as to affect the appetite and thrift of the animal. The conclusion was drawn that furthur fundamental investigation is needed to determine more clearly the requirements of the animals as a basis for the intelligent provision of properly ventilated stables.

Using the results of the above study as a basis, M. A. R. Kelley, of the United States Department of Agriculture, studied the factors influencing the operation of dairy barn ventilation systems, with particular reference to the forced-draft system (*41*). On the basis of the Armsby data for dairy cows, the results showed that as the total heat lost by ventilation and radiation decreased, the temperature inside increased. Estimating the heat production from the individual weight of each cow, the results showed that with the fan system of ventilation 43.7 per cent of the heat generated by the animals was lost by ventilation and 23.5 was lost by radiation.

In considering the design of outtake flues for dairy barn ventilation with a natural draft system on the basis of the heat and carbon-dioxid production of dairy cows, J. L. Strahan, of the Massachusetts station, showed that different breeds of dairy cows present different requirements (*42*). It was found that with a natural draft system it will be reasonable to expect Holsteins to maintain in zero weather a temperature above freezing in a stable 36 by 80 feet inside and housing 40 cows, and at the same time possible to maintain adequate ventilation conditions. On the other hand, it was shown that if Jerseys in low production are housed the stable temperature will drop below 32° F. as soon as the outside temperature goes below 6° if the same rate of air flow through the stable is maintained. Under these conditions the air flow would have to be reduced over 1,200 cubic feet per cow in order to keep the inside temperature up, which would tend to lower the ventilation standard considerably. It is further shown that small Jersey cows on maintenance alone can maintain a temperature difference of from 15° to 17° in well-constructed stables, and it is considered correct to assume that outtake flues may be designed to pass the required amount of air through a stable at a minimum temperature difference of 20° F.

Kelley undertook a further study of the factors influencing the design and operation of animal-barn ventilation systems, in cooperation with several of the State experiment stations, special attention being paid to horse, hog, and dairy barns (*43*). This study showed definitely that the factors influencing the maintenance of the desired temperatures in animal shelters are (1) insulation, (2) tightness of construction, (3) amount of air space each animal is expected to heat, and (4) the desired amount of ventilation in accordance with the type of animal housed and methods used in securing it. One significant conclusion drawn was that further research is needed on the requirements of horses in particular, upon which to base horse-barn design and ventilation.

In further studies of hog-house ventilation conducted at several of the experiment stations (*44*), Kelley showed the possibility of maintaining a reasonably uniform temperature in a barn housing a total weight of 26,775 pounds of hogs by regulating the amount of intake openings. This work also indicated the need for further study of the requirements of hogs and of the factors influencing and producing uniform temperature conditions.

Further studies by Kelley (*45*), in cooperation with the Maine, New York Cornell, and Nebraska stations, on the ventilation of animal shelters and poultry houses, indicated the necessity for more fundamental studies of the ventilation requirements of animals and poultry under exactly controlled conditions. This would suggest the utility in such studies of experimental processes and apparatus similar to those used in respiration calorimetric studies.

Crop storage.—The development of buildings and structures for the storage of crops is a problem of considerable importance in some localities. The importance in such work of careful consideration of the requirements of the crop and its behavior under storage conditions before undertaking to develop storage buildings can not be too strongly emphasized.

Thus studies on the development of potato warehouses by F. E. Fogle at the Michigan station (*46*) began with a consideration of the ventilation, temperature, and moisture requirements of the potato itself and of its rotting tendencies in storage, and proceeded ultimately to the development of the warehouse equipped with a suitable ventilation system for Michigan conditions.

Studies at the Delaware station by T. F. Manns on sweet potato storage in Delaware (*47*) dealt first with diseases of the sweet potato and the influence of moisture, ventilation, and temperature upon storage rots of sweet potatoes, as basic considerations in the development of storage houses and ventilation systems.

These and many other studies at the stations on crop storage show how consideration of the requirements of the crop and its behavior under storage furnishes a basis for the intelligent development of storage structures, and that cooperation between the agricultural engineer and other specialists is of great importance in such work.

DRAINAGE AND IRRIGATION

Other branches of agricultural engineering which merit the same consideration are drainage and irrigation. Numerous unsolved and very pressing problems are offered by each of these branches, and many of them appear to be susceptible of treatment and solution by the same general methods of attack applicable to problems in farm machinery and structures.

Drainage.—Drainage, for instance, is a subject upon which a large amount of work, mostly of a service nature, has been done. With the exception of the studies at the Missouri station on water absorption, run-off, percolation, evaporation, capillary water movement, and erosion under field conditions (*48*), there is practically no record of fundamental studies on this subject by the experiment stations. A consideration of the soil, beyond rather vague empirical treatment, has seldom been undertaken in this country as a basic consideration and logical starting point in drainage studies. Certain foreign agri-

cultural experiment stations, however, have taken the view that the soil and the crop to be grown are the things most vitally concerned in drainage, and have based their investigations on this conception.

A step in this direction was taken recently in studies of underdrainage at the North Carolina station, in cooperation with the United States Department of Agriculture, by H. M. Lynde (*49*). The results indicated that the texture of the soil is the controlling factor in the efficiency of underdrainage, and that in nonhomogeneous soils the spacing and depth of drains should be such as to suit average soil conditions as nearly as possible, and emphasized the importance of studying the influence of the physical and chemical properties of the soil and of different soil treatments and crops on underground run-off.

Investigation on the drainage of irrigated lands has recently been given considerable impetus by several of the experiment stations in the arid and semiarid States. W. W. Weir, in discussing the work by the California station (*50*), has summarized the situation, bringing out particularly the importance of the soil itself as the thing most vitally affected and the factor of primary importance from the standpoint of investigations.

Irrigation.—Irrigation is an agricultural engineering subject which has received much attention at the experiment stations. Practically every experiment station in the irrigated States has had projects in irrigation at one time or another, and there is a record of at least 40 active projects in 12 States. Some of these are obviously too indefinite or general to lay claim to a research status. Many, however, are planned along research lines. The studies have covered almost all phases of irrigation; but it seems that the fundamental factor, the soil, has received relatively little study in its relation to irrigation.

With this factor in view, O. W. Israelsen and F. L. West have conducted studies at the Utah station on the capacity of soils in the natural field condition to absorb and retain irrigation water (*51*). The significant conclusion was drawn that, as a general rule, soils have the capacity to absorb from 0.5 to 1.5 inches of water to each foot of depth of soil that needs moistening, and that the actual capacity of a given soil depends upon its texture and structure. Sandy or gravelly soils naturally retain the smaller amounts and clay loam soils the larger amounts.

Moisture studies of 670 soil samples at the Washington station by R. P. Bean (*52*), conducted principally in connection with border irrigation experiments, showed that, generally speaking, most of the moisture was held in the first 4 feet. Only under exceptionally heavy irrigation did the samples show any pronounced increase of moisture in the fifth and sixth foot. Lateral distribution of the moisture was very uniform, and under experimental conditions 24 hours was sufficient for the irrigation moisture to reach the soil moisture vertically and the soil moisture 36 inches away horizontally.

Studies by Israelsen and L. M. Winsor at the Utah station (*53*), on the net duty of water for staple crops on gravelly sandy loam and fine sandy loam soils, were begun by a consideration of the average permeability of the soils and their maximum capacities for absorbing and retaining water. On this basis the experiments were extended to show the proper use of water on such crops as beets, potatoes, and alfalfa.

The extensive work at the California station on different phases of soil moisture and its movement in relation to irrigation furnishes perhaps the most comprehensive view of the significance of the soil and its hydraulic characteristics as a prime factor in irrigation studies (*54*, *55*). These have brought out especially the significance of such factors as capillarity, evaporation tendencies, organic matter content, and cultivation.

These and numerous other studies indicate that not enough is yet known regarding the hydraulic properties of soil to furnish a sufficiently substantial basis for drainage and irrigation studies. A review of the soils projects at the different experiment stations indicates that there are in operation at least 19 projects at as many stations on the relation of soil moisture and soil moisture movement to the physical and chemical properties of soils. The purely agricultural subject of soils and the engineering subjects of drainage and irrigation are obviously closely related in many respects. It would seem, therefore, that cases might frequently occur in which cooperation between the soils and agricultural engineering departments would be profitable in establishing fundamental hydraulic principles governing the movement and activities of water in soils as bases for drainage and irrigation studies.

FARM-SEWAGE DISPOSAL

Numerous attempts have been made from time to time at several of the experiment stations to meet the pressing demand for so-called practical information on the subject of farm-sewage disposal. A review of the attempts shows them to be generally lacking in the elements of advanced research. The importance of a consideration of the subject from its logical beginning through its scientific contacts to an ultimately practical solution for definite groups and classes of conditions has, however, been emphasized in some of these projects.

The Illinois station has undertaken a cooperative project designed to bring out some of the relations between sewage-tank dimensions and the chemical and biological changes taking place therein. The New Jersey stations have made an important preliminary contribution to the subject in the study by J. W. Thomson of the biology of sewage filters (*56*), and H. E. Murdock at the Montana station has engaged in a study of the factors governing the operation of both septic and Imhoff tanks (*57*). The Kansas Agricultural College has a project on the subject which is also well worthy of attention in that it proposes to develop a fundamental study lasting from 5 to 10 years. In this connection, preliminary studies by H. B. Walker (*58*) on flow characteristics of household sewage from the isolated home have shown that the flow assumptions sometimes made for the design of sewage tanks ranging from 30 to 75 gallons per person per day are too high.

A careful consideration of all the factors involved in the subject of farm-sewage disposal, with particular reference to the object to be accomplished by sewage-disposal measures, indicates the importance of first studying, analyzing, and classifying the conditions to be met by such measures. This was done in a tentative way by R. W. Trullinger, of the Office of Experiment Stations (*59*), but in a manner

sufficiently comprehensive to show the possibilities of such a procedure. The work of H. W. Riley at the New York Cornell station (*60, 61*), of J. R. Haswell at the Pennsylvania station (*62*), and of several of the State departments of health has shown that such a procedure is well worthy of consideration as a preliminary to undertaking studies on farm-sewage disposal.

MATERIALS OF CONSTRUCTION

Construction material is a subject which has developed from a minor miscellaneous matter into one of the most important branches of agricultural engineering; and its rise to such a position can be considered as a natural result of the developement of agricultural engineering as a whole, owing probably to the fact that it bears a close relation to all other branches of the subject.

A great deal of the work done at the experiment stations on materials of construction has been of a very general and apparently comparative or elementary nature. Some of it, however, has had very definite objectives.

Thus studies on the preservative treatment of posts and timbers used in farm structures have a very evident object in view which frequently takes many years to attain. The work at the Iowa station (*63, 64*), for instance, on the preservative treatment of farm timbers, which has been carried on for 16 years, has shown that the quick-growing nondurable Iowa woods can be successfully used for fence-post purposes after having been properly treated with creosote, and that durable fence-post woods, such as white cedar, can be made to last for a long period of years with little deterioration after creosote treatment.

Results of a similar nature have been obtained by J. C. Wooley at the Missouri station (*65*) and by A. K. Chittenden at the Michigan station (*66*). In addition, a nine-year study at the Iowa station of over 700 concrete fence posts of different types has indicated that four 0.25-inch square twisted reinforcement rods are necessary to develop maximum strength without the excessive use of steel (*67*).

An eleven year study of roofing materials at the Iowa station (*67,68*) has indicated the lower durability of materials with a high volatile content, and that a protective layer of mica, sand, or crushed stone has a beneficial influence upon durability. A thirteen year study of shingles at the Pennsylvania station has also yielded valuable data on shingle preservation (*69*).

In studies at the Minnesota station on the effect of organic decomposition products in soils of high vegetable content upon concrete draintile (*70*), Elliott showed that concrete tile always contain free alkali. This reacts with acid organic compounds from peat soils, producing gelatinous compounds which are soluble in water containing carbon dioxid. Therefore, concrete tile as at present made are likely to fail as drainage structures when used in peat soils in the presence of water.

Closely related to this work are the studies conducted by K. Steik at the Wyoming station on the effect of alkali upon Portland cement (*71, 72*). The results of these showed that the chief reacting substance in Portland cement is lime in the form of calcium hydroxid.

Cement set as well in solutions of alkali salts as in water, and magnesium chlorid had the greatest disintegrating effect. Sodium sulphate was more harmful than magnesium sulphate, and the presence of sodium chlorid in solutions of either increased their harmful effect upon cement, while the presence of sodium carbonate retarded it. The tensile strength of cement was the factor most affected by alkali solutions, decreasing most rapidly in all solutions, even when the compressive strength was increased. Waterproofing paints offered only temporary protection against alkali solutions. Obviously this work might be carried much further in the development of resisting processes.

The transmission of heat through wall materials is a matter of vital importance in farm-building design. In this connection G. A. Cumings, of the Colorado station, studied the factors governing the transmission of heat through commercial wall board *(73)*, and found that the average coefficient of heat transmission varied from 0.73 B. T. U. per hour per square foot per degree Fahrenheit difference in temperature from beaver board to 1.01 for sheet rock wall board. These materials were found to be slightly inferior to common lath and plaster 0.5 inch thick and superior to wood in many cases of light construction.

These studies indicate lines and starting points for further study of the respective problems, and bring out the importance of securing effective cooperation in such studies, particularly where needed in the more technical phases of the work.

LAND CLEARING

Work on land clearing at the stations has developed rapidly during recent years; but it is still quite indefinite in nature and it is difficult in many cases to see wherein the principles of research might be applied in the solution of specific problems.

There are at least 13 distinct projects in land clearing at six different stations, most of which deal with comparisons of known or available methods and apparatus for land clearing and the cost thereof. The projects at the Wisconsin and Minnesota stations are among the more comprehensive in that they not only deal with stump and brush removal by explosives and machinery, but have involved the development of new types of plows and cultivating machinery adapted specifically to the breaking and cultivation of the cleared land.

For example, experiments by J. Swenehart and F. W. Duffee, of the Wisconsin station *(74)*, on an improved bush-breaking plow indicated the necessity of redesigning and offsetting the beam to prevent the accumulation of roots and brush. Studies by Swenehart *(75)* on T. N. T. as a land-clearing explosive showed that this material is relatively very insensitive and difficult to detonate, but is quite resistant to such moisture as occurs under ordinary land-clearing conditions. It compared well with 20 per cent dynamite as a blasting explosive. Experiments by Swenehart on the use of picric acid as an agricultural explosive *(76)* resulted in the recommendation of the use of this material in open-air blasting work, provided its cost is less than that of other commercial explosives.

Work on engineering equipment for land clearing by Swenehart (*77*) resulted in mechanical methods and apparatus for removing and handling stumps, the development of which obviously involved an extensive consideration of fundamental physics and mechanics.

Studies by O. I. Bergh and A. H. Benton, of the Minnesota station, on the comparative values of different methods of land clearing (*78*) showed conclusively the advantage of pulling over dynamiting in stump removal, although shattering before pulling had a slight advantage over pulling alone. Forty per cent dynamite gave better results than 20 per cent as an explosive.

Studies by M. J. Thompson, of the Minnesota station, on forced versus delayed systems of clearing stump land (*79*) indicated the superiority of the delayed system.

Experiments by W. Rudolfs, of the New Jersey stations (*80*), demonstrated that sulphur is valueless for killing live stumps, but that rock salt when applied in proper amounts is quite effective.

H. D. Scudder, of the Oregon station (*81*), devised a new method of removing stumps by burning, which involves the use of a furnace, hood, draft pipe, and chimney. By means of these a hole is burned through the base of the stump, converting it into a stove, which eventually destroys itself. This method is especially adapted for the removal of the larger stumps.

The work of Nichols and E. C. Easter, of the Alabama station, has involved considerable work on the clearing of cut-over lands by blasting and other methods (*82, 83*). Apparently blasting is the favored method. In this connection it has been realized by these investigators that not enough is yet known of the factors which govern stump removal by explosives. The conditions of existence of stumps are apparently too variable to permit of an exact application of the principles of ballistics in determining explosive forces necessary for breaking taproots, lifting and inverting the stump, and breaking the lateral roots. However, an attempt has been made to arrive at this information in an indirect manner (*84*), and some fundamental factors have already been established relating to location, depth, and angle of bore hole, type, size, and manner of placing of charge, and other factors which influence the necessary explosive force. The purpose has been obviously to establish some of the requirements which explosives must meet in stump removal to serve somewhat as a guide to explosive manufacturers. This constitutes a distinct departure from the usual comparative testing method and seems to indicate wherein research methods may be applied in some features of the land-clearing problem.

SOIL EROSION

Soil erosion and methods for its prevention offer considerable opportunity for fundamental study, particularly in the South Atlantic and Gulf Coast States. Much of the work hitherto undertaken on this subject at the stations has consisted mainly of comparative tests of terraces of different shapes, sizes, and grades. It is believed that this work should start with a consideration of the factors governing the erosion of soil by water, the influence of different treatments on these factors, and the amount of soil removed by running water under known conditions. Studies could then be intelligently undertaken to develop methods of prevention of erosion.

It is realized that, when dealing with so variable a factor as soil, it is difficult to apply intelligently any established method of research procedure in the solution of the erosion problem. However, a beginning has been made by M. F. Miller, F. L. Duley, and O. B. Price at the Missouri station (*85*, *86*) in studies on water absorption, run-off, percolation, evaporation, and capillary water movement in relation to soil erosion under field conditions. These have already brought out some rather general relations between erosion and types of tillage and nature of vegetation, and have indicated the rapid erosive tendencies of scraped soils and the superiority of a crop-rotation system over continuous grain cropping in this respect. It is believed that elaborations or modifications of this method of work to meet the specific soil, climatic, and farming conditions of other States might aid materially in placing the development of methods of soil erosion prevention upon a more stable basis.

REFERENCES

(1) Indiana Sta. Rpt. 1920, p. 24.
(2) Relation of lug equipment to traction. R. U. Blasingame. Amer. Soc. Agr. Engin. Trans., 15 (1921), pp. 171–177.
(3) Factors influencing the draft of plows. E. V. Collins. Amer. Soc. Agr. Engin. Trans., 14 (1920), pp. 39–55.
(4) Iowa Sta. Rpt. 1921, p. 9.
(5) Iowa Sta. Rpt. 1922, p. 8.
(6) Influence of speed upon the draft of plow. J. B. Davidson, L. J. Fletcher, and E. V. Collins. Amer. Soc. Agr. Engin. Trans., 13 (1919), pp. 69–77.
(7) Nebraska Sta. Rpt. 1921, p. 23.
(8) Missouri Sta. Bul. 179 (Rpt. 1920), p. 14. 1921.
(9) Missouri Sta. Bul. 189 (Rpt. 1921), p. 20.
(10) California Sta. Rpt. 1921, p. 99.
(11) California Sta. Rpt. 1922, p. 21.
(12) Iowa Sta. Rpt. 1921, p. 8.
(13) Iowa Sta. Rpt. 1922, p. 7.
(14) Report on disk harrow investigation. E. V. Collins, C. I. Gunness, A. E. Brandt, and E. J. Stirniman. Agr. Engin., 3 (1922), pp. 44, 45.
(15) A study of the plow bottom and its action upon the furrow slice. E. A. White. Jour. Agr. Research [U. S.], 12 (1918), pp. 149–182; rev. in Amer. Soc. Agr. Engin. Trans., 12 (1918), pp. 42–50.
(16) Agricultural engineering research in farm field equipment. M. L. Nichols. Agr. Engin., 5 (1924), pp. 35–38.
(17) California Sta. Rpt. 1923, p. 50.
(18) Tests of air cleaners for tractor engines. A. H. Hoffman. Agr. Engin., 3 (1922), p. 167.
(19) Efficiency of dust separation in air cleaners for internal-combustion engines. A. H. Hoffman. Agr. Engin., 4 (1923), pp. 89–95, 109–116.
(20) Dust and the tractor engine. A. H. Hoffman. California Sta. Bul. 362. 1923.
(21) A study of sidedraft and tractor hitches. A. H. Hoffman. California Sta. Bul. 349. 1922.
(22) Equalizers and hitches. E. A. White. Amer. Soc. Agr. Engin. Trans., 12 (1918), pp. 124–135.
(23) Iowa Sta. Rpt. 1920, p. 8.
(24) Testing the efficiency of silage cutters. F. W. Duffee. Agr. Engin., 5 (1924), pp. 3–6.
(25) Experiences in the first breaking of peat lands. G. R. B. Elliott and J. L. Larson. Agr. Engin., 4 (1923), pp. 83–88.
(26) The design of farm elevators. W. G. Kaiser and W. A. Foster. Agr. Engin., 2 (1921), pp. 51–56.
(27) Recent developments in farm buildings. F. C. Fenton and A. W. Clyde. Agr. Engin., 3 (1922), pp. 59–62.
(28) Tests of self-supporting barn roofs. A. W. Clyde. Agr. Engin., 4 (1923), pp. 107–109, 118.

(29) Tests of a masonry arch barn roof. A. W. Clyde and H. Giese. Agr. Engin. 5 (1924), pp. 30, 31.
(30) Modern silo construction. J. B. Davidson and M. L. King. Iowa Sta. Bul. 100. 1908.
(31) The Iowa silo. J. B. Davidson and M. L. King. Iowa Sta. Bul. 117. 1910.
(32) Modern silo construction. J. B. Davidson. Iowa Sta. Bul. 141. 1913.
(33) Silo construction. C. K. Shedd and W. A. Foster. Iowa Sta. Bul. 189. 1919.
(34) Iowa Sta. Rpt. 1918. p. 9.
(35) Pennsylvania Sta. Rpt. 1916, pp. 323–348.
(36) Iowa Sta. Rpt. 1922, pp. 7–10.
(37) Measuring silage and capacity of silos. L. W. Chase. Nebraska Sta. Circ. 1. 1917.
(38) Capacities of silos and weights of silage. C. H. Eckles, O. E. Reed, and J. B. Fitch. Missouri Sta. Bul. 164. 1919.
(39) Capacity of silos and weights of silage. C. H. Eckles, O. E. Reed, and J. B. Fitch. Kansas Sta. Bul. 222. 1919.
(40) Some fundamentals of stable ventilation. H. P. Armsby and M. Kriss. Jour. Agr. Research [U. S.], 21 (1921), pp. 343–368.
(41) Test of a fan system of ventilation for dairy barns. M. A. R. Kelley. Agr. Engin., 2 (1921), pp. 203–206.
(42) The design of outtake flues for stable ventilation. J. L. Strahan. Agr. Engin., 2 (1921) pp. 207–209.
(43) Factors influencing the design and operation of farm-building ventilation systems. M. A. R. Kelley. Agr. Engin., 3 (1922), pp. 150–154.
(44) Test of a hog-house ventilation system. M. A. R. Kelley. Agr. Engin., 3 (1922), pp. 164–167.
(45) Recent tests of ventilation systems in farm buildings. M. A. R. Kelley. Agr. Engin., 5 (1924), pp. 7, 8.
(46) The ventilation of potato warehouses. F. E. Fogle. Michigan Sta. Quart. Bul., vol. 5, No. 1, pp. 20–25. 1922.
(47) Sweet potato storage in Delaware. T. F. Manns. Delaware Sta. Bul. 127. 1920.
(48) Missouri Sta. Bul. 189 (Rpt. 1921), p. 54.
(49) Tile drainage investigations in North Carolina. H. M. Lynde. Agr. Engin., 2 (1921), pp. 133–135.
(50) Special features of the drainage of irrigated lands. W. W. Weir. Agr. Engin., 3 (1922), pp. 182–186.
(51) Water-holding capacity of irrigated soils. O. W. Israelsen and F. L. West. Utah Sta. Bul. 183. 1922.
(52) Washington Sta. Bul. 175 (Rpt. 1922), p. 54.
(53) The net duty of water in Sevier valley. O. W. Israelsen and L. M. Winsor, Utah Sta. Bul. 182. 1922.
(54) California Sta. Rpt. 1921, p. 20.
(55) California Sta. Rpt. 1922, p. 104.
(56) A study of the biology of the sprinkling sewage filter. J. W. Thomson. New Jersey Sta. Bul. 352. 1921.
(57) The septic tank—A method of sewage disposal for the isolated home. H. E. Murdock. Montana Sta. Bul. 137. 1920.
(58) Flow characteristics of household sewage from the isolated home. H. B. Walker. Agr. Engin., 4 (1923), pp. 159, 160.
(59) Septic tanks in relation to farm sewage disposal. R. W. Trullinger. Amer. Soc. Agr. Engin. Trans., 11 (1917), pp. 67–76.
(60) Farm-sewage disposal devices. H. W. Riley. Amer. Soc. Agr. Engin. Trans., 15 (1921), pp. 131–135.
(61) Sewage disposal for rural homes. H. W. Riley and J. C. McCurdy. New York State Col. Agr., Cornell Univ. Ext. Bul. 48. 1923.
(62) Septic tanks for the farm. J. R. Haswell. Pennsylvania State Col. Ext. Circ. 89. 1921.
(63) Iowa Sta. Rpt. 1920, p. 49.
(64) Iowa Sta. Rpt. 1921, p. 48.
(65) The durability of fence posts. J. C. Wooley. Missouri Sta. Circ. 108. 1922.
(66) Durability of fence posts. A. K. Chittenden. Michigan Sta. Quart. Bul., vol. 5, No. 3, pp. 137–139. 1923.
(67) Iowa Sta. Rpt. 1922, p. 9.
(68) Iowa Sta. Rpt. 1920, p. 7.

(69) Pennsylvania Sta. Bul. 170 (Bien. Rpt. 1920–21), p. 26. 1922.
(70) Effect of organic decomposition products from high vegetable content soils upon concrete drain tile. G. R. B. Elliott. Jour. Agr. Research [U. S.], 24 (1923), pp. 471–500.
(71) The effect of alkali on Portland cement. K. Steik. Wyoming Sta. Bul. 113. 1917.
(72) The effect of alkali upon Portland cement, II. K. Steik. Wyoming Sta. Bul. 122. 1919.
(73) Heat transmission of commercial wall board. G. A. Cumings. Colorado Sta. Bul. 282. 1923.
(74) Wisconsin Sta. Bul. 352 (Rpt. 1922), pp. 113–116. 1923.
(75) Wisconsin Sta. Bul. 319 (Rpt. 1919), pp. 38, 39. 1920.
(76) Picric acid as an agricultural explosive. J. Swenehart. Agr. Engin., 2 (1921), pp. 246–248.
(77) New engineering developments in land clearing. J. Swenehart. Agr. Engin., 3 (1922), pp. 63–66.
(78) Minnesota Sta., Rpt. Grand Rapids Substa., 1915–1919, pp. 59–70.
(79) Forced v. delayed systems of clearing stump land. M. J. Thompson. Minnesota Sta. Bul. 189. 1920.
(80) Experiments on the value of common rock salt and sulphur for killing live stumps. W. Rudolfs. Soil Sci., 9 (1920), pp. 181–189.
(81) Stump-land reclamation in Oregon. H. D. Scudder. Oregon Sta. Bul. 195. 1922.
(82) Land clearing. M. L. Nichols. Alabama Col. Sta. Circ. 44. 1921.
(83) Clearing cut-over lands in Baldwin County [Ala.]. E. C. Easter and M. L. Nichols. Alabama Col. Sta. Circ. 45. 1922.
(84) (Not yet published.)
(85) Missouri Sta. Bul. 189 (Rpt. 1921), pp. 50–55, 57.
(86) Missouri Sta. Bul. 197 (Rpt. 1922), pp. 81–89.

RANGE INVESTIGATIONS BY THE EXPERIMENT STATIONS

By W. H. Beal, G. Haines, W. A. Hooker, and J. I. Schulte

Various features of the range industry have for many years received attention by the experiment stations in the States where the industry is of particular importance.

Several of the stations have featured range studies prominently. This is especially true of the Arizona station, whose studies date almost from its establishment and cover practically all phases of the subject; the New Mexico station, which has led in the study of the nutritive value and use of range plants for feed, food, and other purposes; the Wyoming station, which has made the composition of range grasses, supplementary feeding, poisonous plants, and diseases of range stock prominent subjects of investigation for many years; the Nevada station, which, among the first to study range plants systematically, established a department of range management in 1915 and now makes range agriculture the leading feature of its work; and the Texas station, which established a well-equipped range station at Sonora in 1916 and also has a division of farm and ranch economics which, among other things, gives attention to range management and the economic and sociological features of ranch life. The Colorado station has undertaken rather elaborate experiments to determine the benefits of deferred and rotative grazing.

The stations have cooperated with the United States Department of Agriculture in some important features of range work.

Principal lines of work.—The range studies of the stations have covered a wide and diverse field, as the following list shows:

Alaska: Range forage.
Arizona: Carrying capacity; range improvement; emergency use of range plants; poisonous plants; rodent injury.
California: Range vegetation; nutritive value of range forage; diseases.
Colorado: Range improvement; revegetation of ranges; supplementary crops; poisonous plants
Guam: Range plants.
Hawaii: Range plants and management.
Idaho: Range management; poisonous plants.
Kansas: Range grasses; range management.
Montana: Range vegetation; grazing experiments; poisonous plants; diseases.
Nebraska: Supplementary feeds and feeding.
Nevada: Range plants; revegetation; poisonous plants; diseases; range management; improving range sheep; protection of range lambs; feeding and finishing of range sheep.
New Mexico: Range vegetation; adaptation of plants to ranges; nutritive value of range plants; poisonous plants; supplementary feeding; range management.
North Dakota: Range plants; range renewal; carrying capacity; diseases.
Oklahoma: Diseases.
Oregon: Range vegetation; poisonous plants; supplementary feeding.
Texas: Range plants; improvement of range sheep; diseases; economic and sociological aspects of ranch life.
Utah: Range surveys and renewal; supplementary feeding.
Washington: Range vegetation; diseases; range management.
Wyoming: Composition of range grasses; poisonous plants; diseases; factors affecting wool; supplementary feeding.

Range vegetation.—Several of the experiment stations have made systematic studies of the vegetation of typical range areas. These studies have dealt especially with such matters as the character, distribution, and relative forage value of range plants and the conditions of their depletion and renewal.

Extensive studies of this kind on the range plants of certain parts of Washington have been reported by the Washington station (*93, 95, 96*)[4], of Montana by the Montana station (*27, 30*), of New Mexico by the New Mexico station (*60, 62*), and of the sheep ranges of Nevada by the Nevada station (*37, 38*). The Arizona station (*3, 4*) has done extensive work on range vegetation and especially on the value of cacti as a range forage. The Oregon station in cooperation with the United States Department of Agriculture[5] has studied the important range plants of the Wallowa National Forest.

The Hawaii station (*23, 24*) and the Guam station (*22*) have reported upon the principal range grasses and forage plants of those islands and the means of improving the range vegetation.

These studies have shown the widely varying character of the vegetation of the ranges and have furnished the basis for important recommendations regarding range management.

Carrying capacity of ranges.—Such observations as have been made on the carrying capacity of ranges show that conditions vary so widely and change so rapidly that it is difficult to generalize or to lay down rules which are universally or permanently applicable. Some of the conclusions reached by the stations which have made most study of the subject are as follows:

The Arizona station (*3*), cooperating with the United States Department of Agriculture, found that much depleted ranges recovered faster when pastured judiciously with approximately all the cattle they could carry than when not grazed at all. The best lands improved under stocking at the rate of one bovine to 20 acres. Overgrazing invariably resulted in the appearance of inferior plants and lessened carrying capacity.

In experiments at Scottsbluff, Nebr. (*36*), 800 acres of dry land range pasture carried 82 steers for 142 days from June 3.

The Nevada station (*49*) found that 2.33 acres per sheep was required for 100 days' pasture under the usual permanent-camp method of grazing, the required acreage being reduced to 1.82 acres by using one-night camps.

The average grazing capacity of New Mexico ranges was found by the station in 1908 (*60*) to be about 35 acres per head of cattle, but varied widely.

In tests of the carrying capacity of native range grasses by the North Dakota station (*74, 77, 80*) it was found that 3 acres furnished pasturage for a steer for 90 days, 5 acres for 135 days, and over 5 acres throughout the season, 150 days. Incidentally the same station (*76*) observed that on 30 acres of fair pasture a steer traveled $1\frac{5}{8}$ miles per day and on 100 acres $3\frac{1}{6}$ miles for food and water.

The Washington station (*93, 96*) has reported upon the conditions which affect the carrying capacity of the grazing areas of Wenaha

---

[4] Italic numbers in parentheses refer to References, p. 123.

[5] U. S. Dept. Agr. Dept. Bul. 545, Important range plants, their life history and forage value. A. W. Sampson. 1917.

National Forest and of the ranges of central Washington, and the California station (*15*) on the gain or loss in weight of cattle of different classes on summer mountain range.

Composition and nutritive value of range plants.—Several of the experiment stations have made studies of the nutritive value of some of the more important range plants. with reference especially to their use as emergency feeds, but also as human food and for other purposes.

Analyses of a number of representative range plants have been reported by the Arizona station (*8, 10*), which has studied particularly the value of cacti (*4*) and of yucca (*6, 9*) as emergency feeds. The station has shown that although these plants are not well-balanced feeds, being deficient especially in protein and fat, they have served to save thousands of range cattle from starvation in time of shortage of other forage.

The earlier growth of range plants was found by the California station (*16*) to be more nutritious than the later. This station has also emphasized the importance of the content of mineral matter in the plants.

The composition, digestibility, and feeding value of cacti, soap weed (*Yucca elata*), chamiza (*Atriplex canescens*), and other characteristic range plants have been the subjects of particularly thorough investigation by the New Mexico station (*59, 61, 63, 64, 67*). The station has shown that these plants as a rule have considerable feeding value but may be objectionable as exclusive feeds. It was found that range cows could be maintained for long periods on soap-weed stems alone, but that the addition of a concentrate like cottonseed meal was of decided advantage because the soap weed is very deficient in protein and fat. No indications of poisonous effects were observed and normal calves were produced by cows fed on the soap weed. Similar results were obtained in feeding sotol heads. Chamiza was found to be of value as a feed, but gave best results when fed in combination with corn stover and other roughages high in fiber. Long-continued feeding on chamiza alone was found to result in digestive disturbances and other troubles, although no specific poisonous effects were observed.

Russian thistle has been shown by the North Dakota station (*73*) to be very rich in mineral matter, especially potash, and highy cathartic when fed exclusively.

Studies by the Texas station (*88, 89*) of the composition and feeding value of several common range plants of the Southwest, including soap weed, Spanish dagger (*Yucca macrocarpa*), bear grass (*Y. glauca*), and sotol (*Dasylirion* sp.), have shown that some of these have emergency value.

Studies by the Colorado station (*17*) of the composition and digestibility of Australian saltbush showed this plant to have considerable feeding value.

The July cutting of prairie hay was found by the North Dakota station (*78*) to be from 12 to 15 per cent more digestible than hay cut in early spring or October.

The study of the composition, digestibility, and comparative feeding value of Wyoming range grasses and native hay has been given much attention by the Wyoming station (*100, 101, 102, 103, 104, 105, 110*) and many of the grasses have been shown to be highly nutritious.

Analyses of several of the more common forage plants of the grazing regions in southern Alaska, particularly blue top (*Calamagrostis langsdorfii*), sedge (*Carex cryptocarpa*), and beech grass (*Elymus mollis*), have been reported by the Alaska stations (*1, 2*).

Supplementary feeding and care.—The study of emergency and supplementary feeds to tide over periods of shortage, to carry range animals through the winter, and to fatten them for the market has been an important feature of the work of many of the experiment stations.

Sorghum silage and cottonseed meal were found by the Arizona station (*7*) to be satisfactory supplementary feeds for range cattle during periods of drought. The same station (*5*) found alfalfa and sorghum silage efficient feeds for fattening range steers for market.

The addition of from 5 to 10 pounds of native hay to the ration of range cows during winter was found by the Montana station (*34*) to be very advantageous in keeping the animals in good breeding condition.

To prevent the extermination of white sage (*Eurotia lanata*), the most important winter forage plant of the Nevada ranges, the Nevada station (*51*) recommends that sheep grazing on such ranges be given a supplementary feeding of cottonseed cake.

In attempts to utilize Russian thistle as silage in a supplementary and emergency feed, the New Mexico station (*68*) found that the silage had a disagreeable odor when fresh and deteriorated rapidly on exposure to the air. To provide the proper fermentation, corn meal was mixed with the Russian thistle in the proportion of 1 part to 100, the result being a more satisfactory silage, on which range cows maintained their weight for 20 days. This station (*65, 66, 70*) has also shown the emergency feeding value of tornillo, mesquite, and pinto beans, and has given considerable attention to supplementing the range with dry farm crops as well as to the utilization of feed by range steers of different ages.

By placing range cattle on corn fodder at the close of the grazing season, the North Dakota station (*76*) secured a daily gain of 2.5 pounds per head and 194 pounds per acre of corn fodder used.

The winter and summer gains of range steers wintered on roughages, the relative advantage of shelter versus feeding in the open, and, in general, different methods of winter feeding and protection have been compared by the Oregon station (*82, 83*).

Winter feeding and protection of range animals and the use of supplementary feeds have been given particular attention by the Wyoming station (*110, 112, 119, 123*). This station has reported experiments in which steers made an average gain of 0.6 pound a day on native hay alone during a period of 70 days and 1.5 pounds when oat and pea silage was added to the ration. A comparison of the gains made by steers on the range and in dry lot during the winter showed that, although the range steers made practically no gain during the winter, they were nearly equal in weight with the others after summer pasturage.

Poisonous plants.—Poisonous plants are the cause of serious losses of stock on the ranges. The Wyoming station (*117*) estimates that such losses amount on the average to about 3 per cent in Wyoming, being greatly increased when wholesome forage is scarce or the stock hungry or in poor condition. The Nevada station (*52, 57*) reports larger

losses of sheep from this cause on Nevada ranges than from all recognized diseases, the losses being increased by overstocking.

The Montana station (*26, 28, 33*) was among the first to investigate this matter, but the Wyoming and Nevada stations have probably pursued it further than any others. These stations have led especially in chemical studies and physiological tests of the toxic principles of the plants, in actual feeding experiments with the plants, and in investigation of remedial and protective measures.

Investigations of the poisonous properties of three species of larkspur (*Delphinium barbeyi, D. glaucescens,, and D. geyeri*) by the Wyoming station (*113, 117*) indicate that the plains larkspur (*D. geyeri*) is the most common and most deadly species in Wyoming and kills more cattle than all the other poisonous plants of the State. It is especially dangerous in its early stages of growth. It was found that "poisoning is due to a definite active principle occurring mostly in the leaves." Other species are also deadly but are less common and hence cause smaller losses. In feeding experiments with steers the Nevada station (*42*) found 2.5 to 3 per cent of the body weight to be a fatal dose of larkspur. Sheep are apparently not affected and horses seldom eat enough to do them harm.

The Nevada station (*42*) finds the lupines poisonous to all classes of stock, but especially to sheep feeding on the pods. Few horses and cattle are poisoned. From one-fourth to one-half pound of the seed produced acute poisoning or death in sheep. The silvery lupine (*Lupinus argenteus*) is reported by the Wyoming station (*117*) to be the most common and most deadly of the lupines. The seeds and pods are the most poisonous parts and drying does not destroy the poison. Poisonous alkaloids were isolated from this plant and studied chemically and physiologically by the Wyoming station (*116*).

The poisonous properties of the water hemlock have been investigated to some extent by the Wyoming station (*117*) but particularly by the Nevada station (*40, 46*). Chemical studies and feeding experiments by the latter showed that the roots of *Cicuta occidentalis* contain a noncrystalline substance having the formula $C_{19} N_{26} O_3$, for which the name cicutoxin is proposed and which is highly poisonous to cattle, sheep, and horses. Old tubers are especially deadly, but young shoots and tops are also poisonous. In feeding experiments at the Nevada station (*46*) about three-fourths pound of old tubers was found to kill a cow, one-half pound a horse, and one-eighth pound a sheep. The poison is a violent one and acts so quickly that there is little time to administer antidotes. Losses due to this plant are especially heavy in case of cattle.

All parts of death camas at every stage of its growth are, according to the Wyoming and Nevada stations, poisonous to all classes of stock but especially to half-starved sheep on overgrazed ranges. The Wyoming station (*106, 108, 117*) has isolated the alkaloidal poison zygadenin from *Zygadenus intermedius* and studied its properties. The Nevada station obtained a similar but apparently not identical alkaloid from *Z. paniculatus*, which killed rabbits in 0.35-gram doses. This station (*47*) found that one-fourth to one-half pound of *Z. paniculatus* made sheep sick, but 3 pounds or more was required to kill them. Three-eighths to 2 pounds made young cattle sick but did not kill them.

The Nevada station (*42*) states that, though the locos are widely distributed in that State, they do not cause serious losses and these are largely confined to sheep and horses. The Wyoming station (*117*) reports that the white loco is widely distributed in that State but does not cause losses comparable with those reported from other States. The purple loco is not so widely distributed. Losses due to locos are confined largely to horses.

Woody aster (*Xylorrhiza parryi*) is reported by the Wyoming station (*117*) to be the cause of large losses of sheep on Wyoming ranges, but these losses have been reduced by better range management. The poisonous principle of the plant has been isolated and studied chemically and physiologically by the station (*107*, *114*). The plant appears to vary in toxicity at different stages of growth, being most poisonous during early growth, but at no time free from toxicity.

That arrow grass (*Triglochin maritima*), in both the green and the dry condition, is under certain conditions poisonous to sheep and cattle was shown by experiments at the Nevada station (*44*). The poisonous principle appears to be a cyanogenetic substance which breaks up in the animal's stomach, liberating sufficient hydrocyanic acid to be quickly fatal, the hay being more deadly than the green plant.

The Nevada station (*45*) found the green leaves, pods, and seeds of milkweeds (*Asclepias mexicana* and *A. speciosa*) to be poisonous to sheep and cattle, the seeds being highly so. Plants dried naturally on the range retained little of their poisonous properties. The toxic principle of the narrow-leaved milkweed (*A. mexicana*), which is far more deadly than the broad-leaved species, was extracted and studied chemically and toxicologically by the Nevada station. The Wyoming station (*117*) reports the broad-leaved milkweed (*A. speciosa*) to be one of the lesser poisonous plants of that State. The Colorado station (*18*, *19*, *20*) reports serious losses of sheep due to eating the whorled milkweed (*A. galioides*). The plant appears to be poisonous at all stages and does not lose its toxicity by drying.

The milk vetch (*Astragalus bisulcatus*) is reported by the Wyoming station (*117*) to be poisonous to sheep and cattle, but ordinarily not particularly dangerous because of its coarse appearance and offensive odor, which repel animals. The Wyoming station (*111*) has obtained a crystalline water-soluble poisonous principle from all parts of the plant which reacts chemically as a glucosid.

In feeding experiments at the Nevada station (*54*) rabbit brush (*Tetradymia glabrata*) was shown to have a cumulative toxic effect which is finally fatal, especially to sheep feeding on it exclusively for some time.

Goldenrod (*Solidago spectabilis* and *S. concinna*), both fresh and dry, is reported by the Nevada station (*42*) to be poisonous to sheep, 1.1 pounds of the green plants proving fatal. No poisonous principles were found in the plant and it is suggested that the reported injury may be due to its high content of ash and especially of potash.

Psoralea (*P. tenuiflora*) is stated by the Wyoming station (*117*) to be undoubtedly poisonous, but because of its bitter taste it is seldom eaten.

The Wyoming station (*117*) states that "while the aconites are poisonous plants, it is pretty definitely settled that they do not poison range stock." The plants are fatally poisonous to sheep and horses,

but cattle are apparently not susceptible. *Aconitum columbianum* was the most poisonous of the species studied by the station.

The Nevada station (*54*) has obtained from saltbush (*Atriplex canescens*) a number of poisonous saponins, the activity of which depends largely upon the time of year when the plants were gathered.

The Nevada station (*42*) states that sheep are the only animals known to be poisoned by false hellebore, which is not widely or abundantly distributed on the ranges of the State.

Losses of range stock occur from time to time as a result of eating certain nonpoisonous plants, as, for example, foxtail (*Hordeum jubatum*). The Nevada station (*43*) found the eating of the bearded heads of this plant particularly fatal to lambing ewes and lambs. In the fatal cases observed the animals were blinded or their mouths were made so sore that they either died of starvation or else fell easy victims to common disease. The injury was due to the lodgment of the barbed awns of the grass in the delicate tissues and membranes of the ear, eye, or mouth.

A comprehensive summary, with illustrations, some colored, of information regarding the principal stock-poisoning plants of Oregon, with an extensive bibliography, has been published by the Oregon station (*84*). A similar bulletin was published by the Nevada station (*42*), especially for the benefit of sheep herders; and, since many of these herders are Basques, a Spanish edition of the bulletin was also issued. Information regarding various plants poisonous to range stock is recorded by the Idaho station (*25*) and the Hawaii station (*23*).

Unusual losses of stock from poisonous plant in 1920 were reported by the Arizona station (*11*), the most important plants mentioned as involved including spreading loco (*Aragallus nothoxus*), Thurber's loco (*Astragalus thurberi*), hairy loco (*A. bigelowii*), tall loco (*A. diphysus* and *A. diphysus macdougali*), purple loco (*Aragallus lamberti*), blue larkspur (*Delphinium scaposum*), prairie larkspur (*D. camporum*), death camas (*Zygadenus elegans*,) and rayless goldenrod or burrow weed (*Bigelowia coronopifolia*).

Diseases affecting range stock.—Among the more important diseases especially affecting range livestock which have been investigated by the experiment stations are tuberculosis, abortion, infectious anemia, chronic pneumonia ("lunger disease"), necrobacillosis, ictero-hemoglobinuria, red water, goiter, and internal parasites. Various other diseases affecting cattle and sheep under range conditions have also been investigated with results of local value.

The intradermic test for tuberculosis has been developed and applied to range cattle by the California station (*12*) with marked success. Water holes were found to be an important source of infection, the organisms retaining their vitality in these holes for about a year. The application of the intradermic test to range cattle is also reported by the Montana station (*31*). The Wyoming station (*122*, *129*) in a study of avian tuberculosis in relation to range cattle found that cattle can be infected with avian tuberculosis when injected beneath the skin and that the intradermic test is the most reliable means of detecting the disease in cattle.

Infectious abortion on the ranges has been the subject of special study by the California station (*13*). The Montana station (*29*) has reported work on this subject and has undertaken the study of the relation of contamination of the water supply to abortion. Tests by

the Wyoming station (*124, 129*) show that a large percentage of range cattle are infected with *Bacillus abortus*. Promising tests of living culture abortion vaccine as an immunizing agent are in progress at this station, and tests of the isolation method of control at this station and at the Oregon station (*85, 86*) with promise of success if practiced with extreme care.

Swamp fever, or infectious anemia of horses, is a widespread disease which has been investigated by several of the experiment stations in the range country, particularly those of North Dakota (*72, 75, 79*), Wyoming (*121, 130*), Nevada (*39*), and Texas (*87, 91, 92*). The specific cause of the disease appears to be uncertain and no cure has been found. The extreme persistence of the disease has been strikingly demonstrated, especially by the North Dakota station (*79*). Some evidence has been secured that the disease is transmitted by certain biting flies, notably the stable fly (*Stomoxys calcitrans*) and the horsefly (*Tabanus septentrionalis*).

The so-called "lunger disease" (progressive pneumonia) of sheep has been given much attention by the Montana station (*35*), and although no progress has been made toward control of the disease it is claimed to have been definitely established "that under ordinary range management no 'lunger' sheep ever recover or even improve in condition, that 'lungers' in the ewe band in the fall will not live through the lambing time, and that those with 'lunger' disease in the spring, if sent to summer range, will die before fall." The causal organism has been isolated.

Necrobacillosis, which is quite prevalent and causes considerable losses on ranges, is being studied by the Wyoming station (*128*), which finds that there are different strains of the causal organism, varying in virulence and morphological characters. Immunity has been produced in rabbits by inoculation with virulent material (*125*). Serums have proved unsatisfactory (*126*). The Montana station has also studied the same disease (*35*), showing the various forms in which this disease manifests itself and suggesting preventive measures.

An obscure hemorrhagic disease (ictero-hemoglobinuria) of range cattle has been studied by the Nevada and Wyoming stations. The Nevada station (*56, 58*) has shown the disease to be distinct from anthrax and hemorrhagic septicemia, with which it was at first confused. Tests showed that the disease may be caused by *Bacillus welchii*, probably in combination with other bacteria. The disease can be cured in the early stages by serum treatment. When it has reached the bloody urine and feces stage no treatment is effective. Vaccination was tested with negative results.

Studies of bovine red water (cystic hematuria) by the Washington station (*94, 98*) indicated that the disease is due to oxalic acid in the feed. The disease is generally fatal.

Investigations by the Montana (*32*), Washington (*97*), and Wisconsin (*99*) stations, extending over a number of years, have shown that hyperplastic goiter is enzootic among all species of domestic animals in certain so-called goitrous regions, being especially prevalent in parts of Washington, Montana, and British Columbia. Iodin appears to be a specific for the trouble.

The life cycles and means of control of various parasites of range sheep, including *Moniezia expansa*, *Thysanosoma actinioides*, and *Sarcocystis tenella*, have been studied by the Wyoming station (*109*,

115, 127). In case of the latter the conditions of infection appear to conform best to the theory of an infective intestinal stage, and control measures based on protection against contaminated food are suggested. The effect of limited grazing on the degree of infection is being studied.

Internal parasites of range stock have also been studied by the Oklahoma station (*81*), Texas station (*91*), and others.

Horseflies, particularly *Tabanus phænops*, which cause great annoyance to cattle on ranges in Nevada and California, have been studied by the Nevada station (*48*). The annoyance is increased by the presence of the horn fly and the common stable fly. Drainage of wet meadows where the flies breed followed by the planting of alfalfa is proposed as the only practical means of control.

Range management.—Some phase or phases of range management have been studied by practically every station in the range country. Especially notable work along this line has been done by the experiment stations in Arizona, California, Colorado, Nevada, New Mexico, Oregon, Texas, Washington, and Wyoming, and this work has indicated various means of improving range practice.

The Arizona station (*3*) was one of the first to study the matter systematically, much of its work being done in cooperation with the United States Department of Agriculture. Finding overstocking and overgrazing to be the chief cause of depleted ranges, this station has advocated, among other things, moderate stocking, rotative grazing, leasing and fencing, Government control, and supplementary feeding. As a result of its studies on the possibilities of revegetation and increasing the carrying capacity of the ranges, the Arizona station has suggested for this purpose the development of the use of certain browsing plants, protected inclosures, and storm-water embankments to distribute and utilize the scanty rainfall to better advantage.

The California station (*14*), as a result of its studies, advocates deferred grazing, cooperative grazing of small flocks in the national forests, and supplementary (winter) feeding to meet the problems of depleted ranges.

The Colorado station (*21*) has studied the grazing of ranges under different methods of management, to see whether the range can be built up while still being grazed, particular attention being given to the effects of overstocking on the range vegetation.

The value of one-night camps as a means of protection against range depletion has been demonstrated by the Nevada station (*37, 38, 41, 49*). The station has also called attention to the advantages of deferred and rotative grazing and of frequent and well-distributed watering places. This station (*50*) has given particular attention to the possibility of reestablishing the white sage (*Eurotia lanata*) on ranges. As a result of its work on revegetation in general this station concludes (*53, 55*) that it is impossible to revegetate or increase the carrying capacity of the open unfenced range. The question of improving range sheep by the use of better bucks and of reducing losses by supplementary feeding and by providing shelter and other means of protection of lambing ewes and lambs is the subject of special study by the Nevada station (*55*).

The New Mexico station (*60, 71*) has studied the conditions determining the carrying capacity of ranges and has made various suggestions and recommendations regarding the rational management and

control of the public grazing lands. Among these are Government control of the grazing lands, rotative grazing, supplementary feeding of range stock, regulation of breeding, use of better bulls, more frequent drinking places, and more frequent and liberal salting.

The Oregon station (*84*) considers rotative grazing one of the most practical means of protection against poisonous plants.

The Texas station, in addition to studying questions relating to the improvement of range stock, has published the results of an exhaustive study (*90*) dealing with ranching as a productive rather than an exploitive industry, utilizing lands largely unsuited to production of cultivated crops and having in mind the permanent use of the land.

The Washington station (*93, 95, 96*), after having investigated various features of range management, has advocated, as means of protection of the range, fencing and moderate and rotative grazing. It also recommends the leasing of grazing lands, as this tends to eliminate injurious competition and overgrazing. The station reached the conclusion that well-managed (rotative) sheep grazing has no bad effect on the reproduction of forests or of grazing plants.

The Wyoming station (*117*) has studied methods of reseeding and improving range vegetation, and emphasizes especially the advantages of rotative grazing, use of one-night camps, avoidance of poisonous plants, and frequent and liberal salting. This station has also studied conditions affecting the quality of wool of range sheep and suggested means of bettering it. Sufficient variation was found in fleeces of range sheep to warrant culling, especially in case of fine-wooled sheep (*118*). Exposure to the weather was found to cause rapid and pronounced deterioration of the wool of fine-wooled open-fleeced sheep (*120*). Sunlight and alkali appeared to be of little importance as compared with other elements of weathering.

The question of the practicability of eradication of poisonous plants from ranges has been studied by some of the stations without very conclusive results. It appears, however, that dependence must be placed largely upon avoidance and preventive measures rather than upon eradication on any extensive scale.

Recognizing that the control of rodents on ranges is of increasing importance, the Arizona station, cooperating with the United States Department of Agriculture, undertook a study of the habits, injury, and means of eradication, especially of the jack rabbit and the kangaroo rat. A report on the latter has been issued[6] which indicates efficient means of control.

Summary.—The foregoing review shows that the work of stations on range problems has covered a wide field. The stations have done much to determine the character of the vegetation and the carrying capacity of ranges, the causes and means of prevention of deterioration, the nutritive value and uses of different kinds of range plants, and ways of promoting the growth of the better kinds of plants. They have also contributed much to efficient methods of supplementary feeding and finishing of range animals, increased our knowledge of poisonous plants and diseases which particularly affect range animals, and made important contributions to the complex problem of range management.

---

[6] U. S. Dept. Agr. Dept. Bul. 1091. Life history of the kangaroo rat (*Dipodomys spectabilis spectabilis*).

The work points especially to the need of better control of the ranges, more restricted and judicious grazing, and better supplementary feeding and care of range animals. It is along the lines of supplementary feeding and care that some of the most important and useful work of the stations is being developed.

REFERENCES

(1) A report to Congress on agriculture in Alaska. W. H. Evans et al. Office of Experiment Stations Bul. 48, p. 13. 1898.
(2) Alaska Stas. Rpt. 1917, p. 77.
(3) The grazing ranges of Arizona. J. J. Thornber. Arizona Sta. Bul. 65. 1910.
(4) Native cacti as emergency forage plants, J. J. Thornber; Nutritive value of cholla fruit, A. E. Vinson. Arizona Sta. Bul. 67. 1911.
(5) Fattening native steers for market, 1920. R. H. Williams. Arizona Sta. Bul. 91. 1920.
(6) Feeding yucca to starving cattle. R. H. Williams. Arizona Agr. Col. Ext. Circ. 21. 1918.
(7) Arizona Sta. Rpt. 1917, p. 469.
(8) Arizona Sta. Rpt. 1917, p. 477.
(9) Arizona Sta. Rpt. 1918, p. 324.
(10) Arizona Sta. Rpt. 1919, p. 411.
(11) Arizona Sta. Rpt. 1920, p. 455.
(12) The intradermal test for tuberculosis in cattle and hogs. C. M. Haring and R. M. Bell. California Sta. Bul. 243. 1914.
(13) Bovine infectious abortion and associated diseases of cattle and new-born calves. G. H. Hart, J. Traum, and F. M. Hayes. California Sta. Bul. 353. 1923.
(14) California Sta. Rpt. 1921, p. 183.
(15) California Sta. Rpt. 1922, p. 54.
(16) California Sta. Rpt. 1922, p. 111.
(17) The Australian saltbush: Its composition and digestibility. Notes on Russian thistle. W. P. Headden. Colorado Sta. Bul. 135. 1908.
(18) A new poisonous plant, the whorled milkweed (*Asclepias verticillata*). G. H. Glover, I. E. Newsom, and W. W. Robbins. Colorado Sta. Bul. 246. 1918.
(19) Whorled milkweed, the worst stock-poisoning plant in Colorado. W. L. May. Colorado Sta. Bul. 255. 1920.
(20) Control of the whorled milkweed in Colorado. W. L. May. Colorado Sta. Bul. 285. 1923.
(21) Colorado Sta. Rpt. 1921, p. 15.
(22) Guam Sta. Rpt. 1913, p. 15.
(23) Grasses and forage plants of Hawaii. C. K. McClelland. Hawaii Sta. Bul. 36. 1915.
(24) Hawaii Sta. Rpt. 1912, p. 78.
(25) Some poisonous plants of Idaho, F. W. Gail; Some suggested remedies, A. R. Hahner. Idaho Sta. Bul. 86. 1916.
(26) Larkspur poisoning of sheep. E. V. Wilcox. Montana Sta. Bul. 15. 1897.
(27) Forage conditions of central Montana. F. A. Spragg. Montana Sta. Bul. 36. 1902.
(28) The loco and some other poisonous plants in Montana. J. W. Blankinship. Montana Sta. Bul. 45. 1903.
(29) Contagious abortion in Montana. H. C. Gardiner. Montana Sta. Bul. 49. 1903.
(30) Native economic plants of Montana. J. W. Blankinship. Montana Sta. Bul. 56. 1905.
(31) The intradermal test in bovine tuberculosis. H. Welch. Montana Sta. Bul. 105. 1915.
(32) Hairlessness and goiter in new-born domestic animals. H. Welch. Montana Sta. Bul. 119. 1917.
(33) Poisonous plants and stock poisoning on the ranges of Montana. D. B. Swingle and H. Welch. Montana Sta. Circ. 51. 1916.
(34) Montana Sta. Rpt. 1917, p. 232.
(35) Montana Sta. Rpt. 1922, p. 26.

(36) Nebraska Sta. Rpt. 1920, p. 35.
(37) A preliminary report on the summer ranges of western Nevada sheep. P. B. Kennedy and S. B. Doten. Nevada Sta. Bul. 51. 1901.
(38) Summer ranges of eastern Nevada sheep. P. B. Kennedy. Nevada Sta. Bul. 55. 1903.
(39) Equine anemia: An account of a recent inquiry into the nature and cause of an obscure and fatal disease among horses in eastern Nevada. W. B. Mack. Nevada Sta. Bul. 68. 1909.
(40) Water hemlock (Cicuta). C. A. Jacobson. Nevada Sta. Bul. 81. 1915.
(41) One-night camps vs. established bed-grounds on Nevada sheep ranges. C. E. Fleming. Nevada Sta. Bul. 94. 1918.
(42) Range plants poisonous to sheep and cattle in Nevada. C. E. Fleming. Nevada Sta. Bul. 95. 1918. English and Spanish editions.
(43) Don't feed fox-tail hay to lambing ewes. C. E. Fleming and N. F. Peterson. Nevada Sta. Bul. 97. 1919.
(44) Arrow-grass, a new stock-poisoning plant (*Triglochin maritima*). C. E. Fleming, N. F. Peterson, et al. Nevada Sta. Bul. 98. 1920.
(45) The narrow-leaved milkweed (*Asclepias mexicana*) and the broad-leaved or showy milkweed (*Asclepias speciosa*), plants poisonous to livestock in Nevada. C. E. Fleming, N. F. Peterson, et al. Nevada Sta. Bul. 99. 1920.
(46) The poison parsnip or water hemlock (*Cicuta occidentalis*), a plant deadly to livestock in Nevada. C. E. Fleming, N. F. Peterson, et al. Nevada Sta. Bul. 100. 1920.
(47) Death camas (*Zygadenus paniculatus* and *Zygadenus venenosus*), plants poisonous to sheep and cattle. C. E. Fleming, N. F. Peterson, et al. Nevada Sta. Bul. 101. 1921.
(48) Horse-flies and cattle. S. B. Doten. Nevada Sta. Bul. 102. 1921.
(49) One-night camps vs. established bed-grounds on Nevada sheep ranges. C. E. Fleming. Nevada Sta. Bul 103. 1922.
(50) Nevada Sta. Rpt. 1917, p. 75.
(51) Nevada Sta. Rpt. 1918, p. 48.
(52) Nevada Sta. Rpt. 1919, p. 39.
(53) Nevada Sta. Rpt. 1920, p. 12.
(54) Nevada Sta. Rpt. 1921, p. 11.
(55) Nevada Sta. Rpt. 1922, p. 17.
(56) Nevada Sta. Rpt. 1922, p. 19.
(57) Nevada Sta. Rpt. 1922, p. 20.
(58) Ictero-hemoglobinuria in cattle. E. Records and L. R. Vawter. Jour. Amer. Vet. Med. Assoc., 60 (1921), p. 155.
(59) Prickly pear and other cacti as food for stock, II. D. Griffiths and R. F. Hare. New Mexico Sta. Bul. 60. 1906.
(60) The range problem in New Mexico. E. O. Wooton. New Mexico Sta. Bul. 66. 1908.
(61) Experiments on the digestibility of prickly pear for cattle. R. F. Hare. New Mexico Sta. Bul. 69. 1908.
(62) The grasses and grass-like plants of New Mexico. E. O. Wooton and P. C. Standley. New Mexico Sta. Bul. 81. 1912.
(63) Range cow maintenance on yucca and sotol. L. Foster and C. W. Humble. New Mexico Sta. Bul. 114. 1918.
(64) Chamiza as an emergency feed for range cattle. L. Foster, J. L. Lantow, and C. P. Wilson. New Mexico Sta. Bul. 125. 1921.
(65) The utilization of feed by range steers of different ages. J. D. Hungerford and L. Foster. New Mexico Sta. Bul. 128. 1921.
(66) The feeding of dry-farm crops to range steers in eastern New Mexico. J. L. Lantow and H. J. Clemmer. New Mexico Sta. Bul. 131. 1922.
(67) The utility of yucca and chamiza as range supplements. L. S. Brown. New Mexico Sta. Bul. 133. 1922.
(68) New Mexico Sta. Rpt. 1918, p. 62.
(69) New Mexico Sta. Rpt. 1921, p. 41.
(70) New Mexico Sta. Rpt. 1921, p. 43.
(71) New Mexico Sta. Rpt. 1922. p. 49.
(72) Swamp fever in horses. L. Van Es, E. D. Harris, and A. F. Schalk. North Dakota Sta. Bul. 94. 1911.
(73) North Dakota Sta. Bul. 146 (Report of Director, 1920), p. 5.
(74) North Dakota Sta. Bul. 146 (Report of Director, 1920), p. 20.
(75) North Dakota Sta. Bul. 146 (Report of Director, 1920), p. 45.

(76) The trail of the short grass steer. J. H. Shepperd. North Dakota Sta. Bul. 154. 1921.
(77) North Dakota Sta. Bul. 159 (Report of Director, 1921), p. 11.
(78) North Dakota Sta. Bul. 159 (Report of Director, 1921), p. 24.
(79) History of a "swamp fever" virus carrier. A. F. Schalk and L. M. Roderick. North Dakota Sta. Bul. 168. 1923.
(80) Carrying capacity of native range grasses in North Dakota. J. H. Shepperd. Jour. Amer. Soc. Agron., 11 (1919), p. 129.
(81) Stomach worms in sheep. J. E. Guberlet. Oklahoma Sta. Bul. 137. 1921.
(82) Fattening lambs—Shelter versus open lot. R. Withycombe and E. L. Potter. Oregon Sta. Bul. 175. 1920.
(83) Growing steers. E. L. Potter and R. Withycombe. Oregon Sta. Bul. 182. 1921.
(84) The principal stock-poisoning plants of Oregon. W. E. Lawrence. Oregon Sta. Bul. 187. 1922.
(85) Infectious abortion of cattle. B. T. Simms and F. W. Miller. Oregon Sta. Bul. 192. 1922.
(86) Oregon Sta. Rpt. 1921–22, p. 40.
(87) Infectious anemia of the horse. M. Francis and R. P. Marsteller. Texas Sta. Bul. 119. 1908.
(88) The utilization of yucca for the maintenance of cattle. J. M. Jones and A. B. Conner. Texas Sta. Bul. 240. 1918.
(89) Feeding values of certain feeding stuffs. G. S. Fraps. Texas Sta. Bul. 245. 1919.
(90) An economic study of a typical ranching area on the Edwards Plateau of Texas. B. Youngblood and A. B. Cox. Texas Sta. Bul. 297. 1922.
(91) Texas Sta. Rpt. 1921, p. 4.
(92) Some recent experiments on infectious anemia of the horse. M. Francis and R. P. Marsteller. Amer. Vet. Rev., 39 (1911), p. 132.
(93) A report on the range conditions of central Washington. J. S. Cotton. Washington Col. Sta. Bul. 60. 1904.
(94) A preliminary report on the investigations of bovine red water (cystic hematuria) in Washington. J. W. Kalkus. Washington Col. Sta. Bul. 112. 1913.
(95) Plants used for food by sheep on the Mica Mountain summer range. R. K. Beattie. Washington Col. Sta. Bul. 113. 1913.
(96) A study of grazing conditions in the Wenaha National Forest. H. T. Darlington. Washington Col. Sta. Bul. 122. 1915.
(97) A study of goitre and associated conditions in domestic animals. J. W. Kalkus. Washington Col. Sta. Bul. 156. 1920.
(98) Red water or bloody urine in cattle. J. W. Kalkus. Western Washington Mo. Bul., vol. 5, No. 9, pp. 127–129. 1917.
(99) Hairless pigs: The cause and remedy. E. B. Hart and H. Steenbock. Wisconsin Sta. Bul. 297. 1918.
(100) Wyoming forage plants and their chemical composition—Studies No. 1. H. G. Knight, F. E. Hepner, and A. Nelson. Wyoming Sta. Bul. 65. 1905.
(101) Digestion experiments with wethers.—Alfalfa and native hay. H. G. Knight, F. E. Hepner, and G. E. Morton. Wyoming Sta. Bul. 69. 1906.
(102) Wyoming forage plants and their chemical composition—Studies No. 2. H. G. Knight, F. E. Hepner, and A. Nelson. Wyoming Sta. Bul. 70. 1906.
(103) Wyoming forage plants and their chemical composition—Studies No. 3. H. G. Knight, F. E. Hepner, and A. Nelson. Wyoming Sta. Bul. 76. 1908.
(104) Digestion experiments, II.—Native hays, oat straw, pea hay, sweet clover, and alfalfa. H. G. Knight, F. E. Hepner, and T. F. McConnell. Wyoming Sta. Bul. 78. 1908.
(105) Wyoming forage plants and their chemical composition—Studies No. 4. H. G. Knight, F. E. Hepner, and A. Nelson. Wyoming Sta. Bul. 87. 1911.
(106) The chemical examination of death camas. F. W. Heyl, S. K. Loy, H. G. Knight, and O. L. Prien. Wyoming Sta. Bul. 94. 1912.
(107) The identification of the woody aster. Wyoming Sta. Bul. 97. 1913.

(108) Zygadenine: The crystallin alkaloid of *Zygadenus intermedius*. S. K. Loy, F. W. Heyl, and F. E. Hepner. Wyoming Sta. Bul. 101. 1913.
(109) The morphology of the sheep tapeworm (*Thysanosoma actinioides*). L. D. Swingle. Wyoming Sta. Bul. 102. 1914.
(110) Cattle feeding. A. D. Faville. Wyoming Sta. Bull. 108. 1915.
(111) The poisonous properties of the two-grooved milk vetch (*Astragalus bisulcatus*). O. A. Beath and E. H. Lehnert. Wyoming Sta. Bul. 112. 1917.
(112) Cattle feeding. A. D. Faville. Wyoming Sta. Bull. 117. 1917.
(113) The chemical examination of three species of larkspurs. O. A. Beath. Wyoming Sta. Bul. 120. 1919.
(114) Chemical and pharmacological examination of the woody aster. O. A. Beath. Wyoming Sta. Bul. 123. 1920.
(115) *Sarcocystis tenella:* The muscle parasite of the sheep. J. W. Scott and E. C. O'Roke. Wyoming Sta. Bul. 124. 1920.
(116) The chemical examination of the silvery lupine. O. A. Beath. Wyoming Sta. Bul. 125. 1920.
(117) Poisonous plants of Wyoming. O. A. Beath. Wyoming Sta. Bul. 126. 1921.
(118) Studies in the variation and correlation of fleeces from range sheep. J. A. Hill. Wyoming Sta. Bul. 127. 1921.
(119) Home-grown feeds for range steers. F. A. Hays. Wyoming Sta. Bul. 128. 1921.
(120) Effects of alkali and weathering upon the wool of range sheep. J. A. Hill. Wyoming Sta. Bul. 131. 1922.
(121) Insect transmission of swamp fever or infectious anemia of horses. J. W. Scott. Wyoming Sta. Bul. 133. 1922.
(122) Avian type of tuberculosis in cattle: Injection and testing. C. Elder and A. M. Lee. Wyoming Sta. Bul. 136. 1923
(123) Feeding yearling steers. F. A. Hays. Wyoming Sta. Circ. 17. 1922.
(124) Abortion disease in Wyoming. C. Elder. Wyoming. Sta. Circ. 18. 1922.
(125) Wyoming Sta. Rpt. 1920, p. 138.
(126) Wyoming Sta. Rpt. 1921, p. 134.
(127) Wyoming Sta. Rpt. 1922, p. 159.
(128) Wyoming Sta. Rpt. 1922, p. 163.
(129) Wyoming Sta. Rpt. 1922, p. 164.
(130) Some additional results obtained in the study of infectious anemia of horses. J. W. Scott. Anat. Rec., 23 (1922), p. 119.

INSULAR EXPERIMENT STATIONS

In addition to the stations conducted in continental United States, similar stations were maintained in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands, as they have been for several years. The appropriations for these stations are made directly to the United States Department of Agriculture, and their supervision is assigned to the Office of Experiment Stations, under the immediate charge of W. H. Evans. Separate reports were published as heretofore upon the work and progress of each of the stations.

The projects of all of the stations were reviewed and materially modified during the year, some being temporarily suspended and efforts concentrated on those that appeared to be most important. There were a number of changes in personnel at the stations, and these also caused some modification of lines of work.

The stations felt acutely the need of additional funds to man and finance properly the work in progress, as well as to undertake new work on certain fundamental problems which await investigation at each station.

STATISTICS OF THE STATIONS

By J. I. Schulte.

For the fiscal year ended June 30, 1922, the total income of the experiment stations was $8,125,404.37, comprising $1,440,000 Federal funds derived under the Hatch and Adams Acts, $4,901,139.50 State support, $183,193.99 income from fees, $907,934.66 returns from the sale of products, $330,078.97 income from miscellaneous sources (including $210,000 Federal appropriations for the insular stations), and $363,057.25 carried over as balances from the previous year.

The value of additions to the equipment of the stations during the year was reported as follows:

Buildings	$735, 823. 16
Library	27, 362. 20
Apparatus	92, 123. 16
Farm implements	115, 266. 80
Livestock	110, 665. 32
Miscellaneous	104, 024. 48
Total	1, 185, 265. 12

In the work of administration and inquiry the stations employed 2,166 persons, of whom 1,100 were also members of the teaching staff of the colleges and 364 assisted in the various lines of extension work. During the year the stations report having issued 1,064 publications (not all of which were received by this office during the fiscal year). The list includes annual reports, bulletins, and circulars, aggregating 24,592 pages, and these were distributed to 889,394 addresses on the regular mailing list.

The statistics of the stations by States are given in detail in the tables following:

TABLE 2.—*General statistics, 1922*

Station	Location	Director	Date of original organization	Date of organization under Hatch Act	Number on staff	Number of teachers on staff	Number of persons on staff who assist in extension work	Publications during fiscal year 1921–22: Number	Publications during fiscal year 1921–22: Pages	Number of names on mailing list
Alabama (College)	Auburn	D. T. Gray	Feb. —, 1883	Feb. 24, 1888	23	10	4	4	28	7,000
Alabama (Canebrake)	Uniontown	W. A. Cammack	Jan. 1, 1886	Apr. 1, 1888						
Alabama	Tuskegee Institute	G. W. Carver	Feb. 15, 1897		5	4				
Alaska	Sitka	C. C. Georgeson			6			1	75	
Arizona	Tucson	J. J. Thornber		—, 1889	24	16	5	9	90	9,250
Arkansas	Fayetteville	Bradford Knapp		—, 1887	28	26		7	242	12,941
California	Berkeley	C. M. Haring	—, 1875	Mar. —, 1888	123	94	80	55	1,630	40,697
Colorado	Fort Collins	C. P. Gillette		Feb. 29, 1888	41	23	4	10	387	2,550
Connecticut (State)	New Haven	E. H. Jenkins	Oct. 1, 1875	May 18, 1887	24	1		3	460	9,912
Connecticut (Storrs)	Storrs	do		do	12	6		3	114	6,200
Delaware	Newark	C. A. McCue		Feb. 21, 1888	14	9	3	4	122	8,500
Florida	Gainesville	Wilmon Newell		—, 1888	16	1	2	24	168	18,000
Georgia	Experiment	H. P. Stuckey	Feb. 18, 1888	July 1, 1889	7		7	45	111	6,500
Guam	Guam	C. W. Edwards			4			4	198	
Hawaii	Honolulu	J. M. Westgate			5		2	2	95	
Idaho	Moscow	E. J. Iddings		Feb. 26, 1892	34	21	10	21	278	11,785
Illinois	Urbana	Eugene Davenport		Mar. 21, 1888	106	70	30	29	771	42,000
Indiana	Lafayette	G. I. Christie	—, 1885	Jan. —, 1888	67	21		21	516	38,478
Iowa	Ames	C. F. Curtiss		Feb. 17, 1888	80	30		29	682	30,500
Kansas	Manhattan	F. D. Farrell		Feb. 8, 1888	87	39		10	334	11,000
Kentucky	Lexington	T. P. Cooper	Sept. —, 1885	Apr. —, 1888	55	24	18	14	661	9,000
Louisiana (Sugar)	New Orleans	W. R. Dodson	Sept. —, 1885							
Louisiana (State)	Baton Rouge	do	Apr. —, 1886		28	2	10	4	89	8,000
Louisiana (North)	Calhoun	do	May —, 1887							
Maine	Orono	W. J. Morse	Mar. —, 1885	Oct. 1, 1887	14			16	953	19,342
Maryland	College Park	H. J. Patterson	—, 1888	Apr. —, 1888	29	10		8	250	22,000
Massachusetts	Amherst[1]	S. B. Haskell	—, 1882	Mar. 2, 1888	46	14	1	26	427	18,367
Michigan	East Lansing	R. S. Shaw		Feb. 26, 1888	77	61	5	23	1,258	45,000
Minnesota	University Farm, St. Paul	W. C. Coffey	Mar. 7, 1885	—, 1888	98	78	2	9	598	12,000
Mississippi	Agricultural College	J. E. Ricks		Jan. 27, 1888	41	17	2	16	204	15,000
Missouri (College)	Columbia	F. B. Mumford		Jan. —, 1888	61	44		78	1,222	6,368
Missouri (Fruit)	Mountain Grove	F. W. Faurot	Feb. 1, 1900		4					
Montana	Bozeman	F. B. Linfield		July 1, 1893	38	17	7	16	468	10,775
Nebraska	Lincoln	E. A. Burnett	Dec. 16, 1884	June 13, 1887	40	17		8	333	7,925
Nevada	Reno	S. B. Doten		Dec. —, 1887	8	1		2	33	6,000
New Hampshire	Durham	J. C. Kendall	—, 1886	Aug. 4, 1887	22	17		13	245	9,000
New Jersey (State)	New Brunswick	J. G. Lipman	Mar. 10, 1880		50	35	14	129	2,243	15,000
New Jersey (College)	do	do		Apr. 26, 1888	25					

New Mexico	Agricultural College	Fabian Garcia		Dec. 14, 1889	18	13	5	39	439	10,000
New York (State)	Geneva	R. W. Thatcher	Mar. —, 1882		45			21	502	24,338
New York (Cornell)	Ithaca	A. R. Mann	——, 1879	Apr. —, 1888	62	54	7	30	2,097	2,896
North Carolina (College)	West Raleigh	B. W. Kilgore	Mar. 12, 1877	Mar. 7, 1887	49	3	2	3	149	7,562
North Dakota	Agricultural College	P. F. Trowbridge		Mar. —, 1890	37	9	2	15	304	9,100
Ohio	Wooster	C. G. Williams	Apr. 25, 1882	Apr. 2, 1888	57	3	1	92	1,813	72,367
Oklahoma	Stillwater	C. T. Dowell		Dec. 25, 1890	23	16		7	32	16,500
Oregon	Corvallis	J. T. Jardine		July —, 1888	57	30		13	333	1,448
Pennsylvania	State College	R. L. Watts		June 30, 1887	62	62	62	6	152	42,500
Pennsylvania (Nutrition)	do	H. P. Armsby [2]	——, 1907		7					
Porto Rico	Mayaguez	D. W. May			9		1	2	51	3,485
Rhode Island	Kingston	B. L. Hartwell		July 30, 1888	12	3		7	216	2,800
South Carolina	Clemson College	H. W. Barre		Jan. —, 1888	29	10	7	6	240	5,000
South Dakota	Brookings	J. W. Wilson		Mar. 13, 1887	21	19		7	200	22,000
Tennessee	Knoxville	H. A. Morgan	June 8, 1882	Aug. 4, 1887	24	1		3	59	12,000
Texas	College Station	B. Youngblood		Apr. 3, 1889	48	1		21	648	61,789
Utah	Logan	William Peterson		——, 1890	37	26	18	12	218	11,000
Vermont	Burlington	J. L. Hills	Nov. 24, 1886	Feb. 28, 1888	13	8	2	5	644	8,000
Virginia	Blacksburg	A. W. Drinkard, jr	——, 1888	——, 1891	30	11		8	164	12,000
Virgin Islands	St. Croix	J. B. Thompson			2			2	23	521
Washington	Pullman	E. C. Johnson		——, 1891	43	13		4	164	13,625
West Virginia	Morgantown	H. G. Knight		June 11, 1888	35	22	2	1	24	28,000
Wisconsin	Madison	H. L. Russell	——, 1883	——, 1887	88	76	48	16	684	56,873
Wyoming	Laramie	A. D. Faville		Mar. 1, 1891	16	12	1	7	151	6,000
Total					2,166	1,100	364	1,064	24,592	889,394

[1] In 1882 the State organized a station here and maintained it until June 18, 1895, when it was combined with the Hatch station at the same place.
[2] Died Oct. 19, 1921.

TABLE 3.—*Revenue and additions to equipment, 1922*

Station	Federal: Hatch fund	Federal: Adams fund	State	Balances from previous year [1]	Fees	Sales	Miscellaneous	Total	Additions to equipment: Buildings	Library	Apparatus	Farm implements	Livestock	Miscellaneous	Total
Alabama	$15,000.00	$15,000.00	$34,500.00	$6,352.92		$4,897.66		$75,750.58	$7,600.00	$500.00	$7,100.00	$1,000.00	$1,625.00	$500.00	$18,325.00
Alaska							[2] $75,000.00	75,000.00							
Arizona	15,000.00	15,000.00	66,531.60			12,110.99		108,642.59	5,383.38	1.00	2,413.14	1,633.24	1,794.14	221.02	11,445.92
Arkansas	15,000.00	15,000.00	56,945.74			2,554.22		89,499.96		99.10	1,297.53	2,171.12	962.00		4,529.75
California [3]	15,000.00	15,000.00	380,000.00					410,000.00	76,589.47	2,370.86	3,931.90	8,284.97	2,983.75	3,424.09	97,585.04
Colorado	15,000.00	15,000.00	109,686.22	9,478.31				149,164.53	7,507.65	575.00	3,676.00	586.00	4,525.00	19,464.89	36,334.54
Connecticut (State)	7,500.00	7,500.00	61,121.50	40.22	$8,681.78		11,503.61	96,347.11	349.09	778.95	178.44	415.50	55.00	518.83	2,295.81
Connecticut (Storrs)	7,500.00	7,500.00	17,500.00	2,691.78			17,796.92	52,988.70					2,000.00	250.00	2,250.00
Delaware	15,000.00	15,000.00	15,000.00			6,985.22	500.00	52,485.22	279.69	495.94		1,265.00			2,040.63
Florida	15,000.00	15,000.00	55,000.00	3,739.32		6,503.00		95,242.32	12,032.81	729.68	568.48	1,038.69	1,161.90	192.14	15,723.70
Georgia	15,000.00	15,000.00	11,765.64	3,344.69		7,558.49		52,668.82	1,500.00	1,205.76	1,000.00	3,981.64	434.85		8,122.25
Guam							[2] 15,000.00	15,000.00							
Hawaii							[2] 50,000.00	50,000.00							
Idaho	15,000.00	15,000.00	10,032.51			2,765.18	988.33	43,786.02	400.00	200.00	2,100.00	1,000.00	1,000.00	400.00	5,100.00
Illinois	15,000.00	15,000.00	310,293.85	37,884.08		57,174.92		435,352.85	174,011.00					23,515.32	197,526.32
Indiana	15,000.00	15,000.00	215,982.87	42,635.45	29,530.01	110,058.95	11,986.91	440,194.19	12,542.63	1,019.82	509.15	6,126.61	10,714.48	1,998.79	32,911.48
Iowa	15,000.00	15,000.00	250,000.00	30,073.25		32,559.59	246.66	342,879.50			4,886.40	577.25	5,642.20	514.47	11,620.32
Kansas	15,000.00	15,000.00	97,000.00	7,835.14		34,084.87		168,920.01	279,733.00	75.70	80.00	5,984.04	1,200.79	396.51	287,470.04
Kentucky	15,000.00	15,000.00	50,000.00	15,050.38	42,177.91	33,107.26	5,700.00	176,035.55		516.54	637.32	1,101.50	690.00	190.18	3,135.54
Louisiana	15,000.00	15,000.00	50,000.04	31,209.92				111,209.96	7,127.00	379.02	2,340.69	3,249.17	1,216.30	2,180.85	16,493.03
Maine	15,000.00	15,000.00	31,146.23		12,028.48		352.12	73,526.83		483.68	501.60	424.50	26.25	125.31	1,561.35
Maryland	15,000.00	15,000.00	49,623.67			11,018.27		90,641.94		346.71	895.20	1,238.04	500.00	177.95	3,157.90
Massachusetts	15,000.00	15,000.00	99,152.86		18,648.95	9,690.25	378.20	157,870.26	1,010.12	635.39	292.09	1,167.54	230.82		3,335.96
Michigan	15,000.00	15,000.00	90,000.00		40.00	6,453.84	4,588.62	131,082.46	5,875.48	671.92	1,266.52	3,062.15	1,841.60		12,717.67
Minnesota	15,000.00	15,000.00	306,942.51			121,366.10	2,504.09	460,812.70	21,184.34	1,794.76	3,461.30	8,790.44	9,844.53		45,075.37
Mississippi	15,000.00	15,000.00	102,377.14	5,545.72	149.00	15,090.45	405.84	153,568.15	183.36	259.03	2,212.37	1,121.25	6,770.00	1,147.01	11,693.02
Missouri	15,000.00	15,000.00	42,086.66	2,045.21	23,043.59	14,535.11		111,710.57	318.95	606.49	1,194.75	571.93	3,540.82		6,232.94
Montana	15,000.00	15,000.00	134,468.57			8,582.64		173,051.21	15,312.00	500.00	482.00	5,180.00	600.00	1,618.00	23,692.00
Nebraska	15,000.00	15,000.00	71,741.83	13,358.13		71,703.27		186,803.23		459.39	3,521.15	4,574.87	9,658.56	12,947.72	31,161.69
Nevada	15,000.00	15,000.00	1,878.15	329.45		1,811.55		34,019.15	1,861.34	166.74	387.42	79.75	1,472.80	38.00	4,006.05
New Hampshire	15,000.00	15,000.00	5,000.00	1,215.92		2,910.97	13,064.35	52,191.24		450.00	1,283.69	83.75	325.00	667.03	2,809.47
New Jersey (College)	15,000.00	15,000.00						30,000.00	728.50	1,355.47	2,661.63	49.91	666.70	2,239.36	7,701.57
New Jersey (State)			142,956.51		47,550.02	27,093.49	2,173.37	219,773.39							
New Mexico	15,000.00	15,000.00	7,500.00	18,150.16		9,084.54		64,734.70	1,596.40	118.96	476.07	863.73	1,893.59	126.56	5,075.31
New York (Cornell)	13,500.00	13,500.00	183,474.32			34,449.97	5,011.81	249,936.10	10,087.02	1,074.62	4,002.35	3,633.21	433.96	1,615.95	20,847.11

New York (State) [4]	1,500.00	1,500.00	198,354.63	2,836.47				204,191.10		1,890.00	4,200.00	2,600.00		1,800.00	10,490.00
North Carolina	15,000.00	15,000.00	162,737.00	920.49		3,237.39	4,180.48	201,075.36	5,771.01		179.42	2,170.12	1,250.00	532.10	9,902.65
North Dakota	15,000.00	15,000.00	151,334.43	7,699.27			20,082.97	209,116.67	6,500.00	64.01	1,234.67	7,044.42	7,140.84		21,983.94
Ohio	15,000.00	15,000.00	310,640.85	43,282.80		40,304.10		424,227.75		943.91	3,647.79	3,647.79	1,015.00	3,000.00	12,254.49
Oklahoma	15,000.00	15,000.00	10,500.00	2,525.68		5,094.84		48,120.52		553.59	1,398.53	526.61	863.70		3,342.43
Oregon	15,000.00	15,000.00	107,543.78	36,023.59		36,860.50	4,000.00	214,427.87	3,500.00	25.00	3,110.72	4,015.79	4,457.00	2,090.82	17,199.33
Pennsylvania	15,000.00	15,000.00	36,435.63		1,344.25	12,755.27	6,780.31	87,315.46		669.63	3,804.65	169.17	3,959.13	181.18	8,783.76
Porto Rico							[2] 50,000.00	50,000.00	2,258.09	183.02	303.69	296.49			3,041.29
Rhode Island	15,000.00	15,000.00	9,051.80	447.31		5,495.72		44,994.83	463.00	460.00	223.00	177.00	50.00	676.00	2,052.00
South Carolina	15,000.00	15,000.00	57,987.02			4,182.29		92,169.31	1,200.00	150.00	400.00	1,000.00	1,000.00	400.00	4,150.00
South Dakota	15,000.00	15,000.00	14,420.00	7,633.98		2,018.30	5,896.59	59,968.87		125.00	595.23	600.00	225.00		1,545.28
Tennessee	15,000.00	15,000.00	33,294.89			233.21		63,528.10	4,000.00	459.34	239.35	3,188.66	2,500.00	399.21	10,836.59
Texas	15,000.00	15,000.00	201,535.00	3,028.30		54,393.27		288,956.57	13,540.33	601.89	10,275.44	7,904.08	1,100.00	11,103.04	44,524.78
Utah	15,000.00	15,000.00	50,123.77	9,513.39		10,527.07		100,1[illegible]4.23	2,500.00	300.00	700.00		500.00	400.00	4,400.00
Vermont	15,000.00	15,000.00				177.60		30,177.60	184.18	58.38	1,145.89	98.83	152.50		1,639.78
Virginia	15,000.00	15,000.00	45,297.50	12,288.39		[illegible],325.15	550.10	9[illegible],461.14	1,807.26	557.03	182.97	951.75		222.01	3,721.02
Virgin Islands							[2] 20,000.00	20,000.00	5,667.45	8.10	12.98	144.94			5,833.47
Washington	15,000.00	15,000.00	104,674.78	1,499.92		49,598.59		185,773.29	3,218.61	522.31	1,106.02	3,118.60	2,234.00	493.69	10,743.23
West Virginia	15,000.00	15,000.00	120,000.00			27,313.83	1,387.69	178,701.52	30,000.00	600.00	1,520.00	1,753.73	2,525.00	829.24	37,227.97
Wisconsin	15,000.00	15,000.00	215,000.00					245,000.00	12,000.00	1,320.46	3,154.71	4,322.04	3,296.60	2,224.89	26,318.70
Wyoming	15,000.00	15,000.00	12,500.00	4,377.61		3,266.73		50,144.34			1,277.86	2,2[illegible]0.98	4,536.50	5,202.29	13,297.63
Total	720,000.00	720,000.00	4,901,139.50	[illegible]63,057.25	183,193.99	907,934.66	330,078.97	8,125,404.3[illegible]	735,823.1[illegible]	27,3[illegible]2.20	92,123.1[illegible]	115,266.80	110,665.32	104,024.48	1,185,265.12

[1] Not including balances from Federal funds.
[2] Supported by direct appropriation to the United States Department of Agriculture.
[3] The resources from other than Federal funds are estimated.
[4] Including balances from previous year: $7.84 Hatch and $0.24 Adams.

TABLE 4.—*Expenditures from United States appropriations received under*

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Publications	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	$15,000.00	$8,912.48	$1,759.00	$127.91	$341.08	$186.76		$388.43
Arizona	15,000.00	8,574.87	392.58	73.20	915.24	74.88		469.30
Arkansas	15,000.00	8,093.56	2,001.04	568.43	235.51	186.39	$93.42	192.96
Ca'ifornia	15,000.00	15,000.00						
Colorado	15,000.00	11,711.91	1,704.56	497.00	33.87	57.92		30.19
Connecticut (State)	7,500.00	7,500.00						
Connecticut (Storrs)	7,500.00	7,500.00						
Del ,ware	15,000.00	9,656.33	851.41	1,803.89	762.61	63.88	239.36	309.68
Florida	15,000.00	11,769.14	382.01		5.18	26.85	17.02	145.31
Georgia	15,000.00	8,495.96	1,784.57	725.59	708.41	189.93	610.33	54.00
Idaho	15,000.00	10,697.14	2,504.31	373.38	13.31	28.74	91.25	107.36
Illinois	15,000.00	13,929.06	770.50	271.18	29.26			
Indiana	15,000.00	14,162.50	715.81		20.50			19.05
Iowa	15,000.00	8,415.00	290.35	1,111.60	357.90	40.42	143.29	93.00
Kansas	15,000.00	9,883.33	4,703.02	9.68	104.62			2.60
Kentucky	15,000.00	15,000.00						
Louisiana	15,000.00	9,056.81	2,964.18	325.52	164.44	56.83	435.69	
Maine	15,000.00	6,503.78	2,331.08	241.48	437.49	234.04	706.63	34.75
Maryland	15,000.00	13,183.12	853.18	578.88	8.14		196.31	12.77
Massachusetts	15,000.00	14,632.50	367.50					
Michigan	15,000.00	12,947.75	2,052.25					
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	9,600.04	3,022.73		215.80	104.35	458.48	
Missouri	15,000.00	11,260.82	1,542.85		80.80	185.88	40.44	182.64
Montana	15,000.00	14,385.00		156.35	416.05	.86		2.25
Nebraska	15,000.00	14,580.00	420.00					
Nevada	15.000.00	9,471.65	2,816.82	105.91	277.53	37.58	98.42	
New Hampshire	15,000.00	9,916.00	1,022.40	804.84	647.68	303.79	600.00	149.68
New Jersey	15,000.00	10,004.02	683.46	512.96	300.28	46.95	637.50	192.10
New Mexico	15,000.00	5,145.28	3,523.84	1,713.94	172.74	218.75	146.50	5.64
New York (State)	1,500.00	333.28	1,163.25					
New York (Cornell)	13,500.00	9,520.00	1,832.90		16.34	27.20	71.37	188.86
North Carolina	15,000.00	9,096.33	4,012.65		240.72	223.48		
North Dakota	15,000.00	15,000.00						
Ohio	15,000.00	13,548.32	1,451.68					
Oklahoma	15,000.00	6,940.75	2,434.12	500.85	255.27	28.33	50.23	471.73
Oregon	15,000.00	9,715.67	3,038.28	683.16	33.39	26.39	28.10	308.15
Pennsylvania	15,000.00	11,800.00	749.10	1,609.67	1.25	62.82	4.50	39.50
Rhode Island	15,000.00	6,912.95	4,342.02	1,857.81	172.35	270.61	114.21	16.10
South Carolina	15,000.00	7,919.42	2,636.74	122.67	408.17	139.58	132.84	178.97
South Dakota	15,000.00	8,364.93	2.085.11	3,285.58	77.08	15.86		75.24
Tennessee	15,000.00	11,017.62	451.40	651.64	268.69	38.78	941.04	25.29
Texas	15,000.00	13,329.99	32.50		309.61		14.90	
Utah	15,000.00	11,096.28	2,276.01		32.48	36.63		778.49
Vermont	15,000.00	6,025.83	1,295.48	4,352.35	226.57	69.40	841.00	22.53
Virginia	15,000.00	9,714.92	3,013.10	263.64	325.80	145.28	57.82	21.22
Washington	15,000.00	8,536.51	2,371.78	2,139.91	44.11		71.82	53.04
West Virginia	15,000.00	12,537.49	704.25			56.55		
Wisconsin	15,000.00	9,075.77	2,494.80		22.61	2.85	19.50	580.04
Wyoming	15,000.00	10,833.51	24.22	485.73			252.96	386.19
Total	720,000.00	516,307.62	75,868.84	25,954.75	8,682.88	3,188.56	7,114.93	5,537.06

the act of March 2, 1887 (Hatch Act), for the year ended June 30, 1922

Classified expenditures											
Seeds, plants, and sundry supplies	Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and repairs	Balances
$270.72	$384.65	$373.32	$452.77	$392.64	$534.52	--------	$140.80	$97.18	------	$637.74	----
260.36	--------	790.56	1.00	350.57	504.20	$1,454.33	228.50	606.19	------	304.22	----
1,131.89	246.01	624.81	--------	398.71	19.25	424.16	30.00	415.56	------	338.30	----
96.46	--------	276.95	36.67	38.15	134.05	14.47	120.00	211.61	------	36.19	----
--------	--------	--------	--------	--------	--------	--------	--------	--------	------	--------	----
124.61	21.73	--------	128.84	266.52	173.06	29.14	--------	528.63	$31.06	9.25	----
210.84	220.88	468.00	626.96	170.87	21.75	113.98	--------	490.96	4.65	325.60	----
815.99	561.51	126.41	142.27	422.61	54.95	18.95	17.00	271.52	------	--------	----
231.56	4.10	199.50	34.24	133.50	7.10	109.95	--------	385.39	------	79.17	----
23.00	--------	--------	--------	8.25	--------	--------	36.00	14.89	------	--------	----
915.74	--------	3,474.85	--------	52.10	10.82	--------	--------	94.93	------	--------	----
205.80	--------	--------	--------	32.10	7.98	--------	--------	50.87	------	--------	----
224.59	10.00	403.05	93.65	122.31	232.70	--------	--------	562.35	75.56	272.32	----
893.08	--------	2,191.55	438.45	236.62	34.34	70.92	--------	279.43	------	366.36	----
102.78	--------	--------	27.88	.60	--------	36.34	--------	--------	------	--------	----
--------	--------	--------	--------	--------	--------	--------	--------	--------	------	--------	----
--------	--------	--------	--------	--------	--------	--------	--------	--------	------	--------	----
576.82	21.37	293.45	--------	16.70	70.00	--------	461.52	78.12	1.18	79.44	----
580.27	--------	741.26	12.00	58.28	10.88	19.21	57.51	222.41	------	4.75	----
2.09	--------	--------	--------	--------	34.42	--------	--------	--------	------	2.98	----
225.48	--------	67.82	32.24	129.10	43.25	4.50	542.82	617.54	------	529.34	----
166.10	158.96	--------	401.81	171.77	63.96	207.15	--------	363.69	------	22.17	----
478.18	75.53	--------	25.50	32.87	80.81	5.00	--------	1,857.20	28.50	39.14	----
465.06	130.53	1,138.59	102.76	661.14	63.53	--------	556.77	436.24	------	518.69	----
--------	--------	--------	--------	--------	--------	--------	--------	3.06	------	--------	$0.41
323.81	10.00	--------	--------	461.47	158.43	581.28	--------	292.80	------	15.54	----
289.99	392.30	736.07	--------	--------	--------	--------	--------	--------	------	8.46	----
--------	--------	--------	--------	--------	--------	--------	--------	--------	------	--------	----
788.60	33.64	1,485.91	181.77	370.48	43.83	356.50	786.90	192.59	------	78.50	----
151.01	28.99	--------	9.50	127.34	--------	72.00	--------	776.58	1.44	--------	----
342.99	46.11	--------	--------	13.98	--------	--------	--------	330.08	------	--------	----
324.65	243.02	403.96	111.85	127.96	18.80	.80	--------	37.92	.90	44.09	----
536.62	603.93	932.66	723.91	353.69	170.90	--------	6.00	84.71	------	49.19	----
561.32	--------	141.94	--------	64.99	28.85	61.25	225.00	--------	------	12.85	----
203.31	2.50	--------	380.81	230.18	332.14	40.32	--------	233.47	------	182.81	----
14.50	--------	--------	5.00	652.01	365.74	--------	--------	--------	------	275.75	----
203.81	--------	113.71	10.15	8.47	3.63	94.35	--------	321.72	------	24.27	----
899.29	261.36	--------	45.04	75.45	78.66	219.13	--------	504.93	------	82.98	----
721.26	115.28	71.04	186.50	177.59	94.97	--------	--------	40.00	------	51.58	----
189.30	51.69	--------	--------	22.14	75.85	335.25	--------	1,108.60	------	--------	----
477.81	128.01	--------	--------	371.40	--------	--------	--------	461.19	------	263.30	----
1,134.27	194.03	12.50	--------	53.29	95.22	1,190.06	--------	125.06	------	--------	----
93.38	--------	2,106.50	--------	190.10	9.75	250.13	--------	--------	------	367.53	----
15,257.34	3,946.13	17,174.41	4,211.57	6,995.95	3,578.34	5,709.17	3,208.82	12,097.42	143.29	5,022.51	.41

TABLE 5.—*Expenditures from United States appropriations received under*

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies	Seeds, plants, and sundry supplies
Alabama	$15,000.00	$10,219.06	$383.77	$13.41	$66.86		$683.70	$175.45
Arizona	15,000.00	11,824.01	553.42	106.12	58.43		98.27	70.43
Arkansas	15,000.00	9,521.25	1,944.93	65.58	49.71	$2.10	712.72	671.29
California	15,000.00	9,299.96	1,735.68	74.46	4.08	59.03	934.24	669.19
Colorado	15,000.00	13,019.23	196.85	9.27	17.25		987.70	82.81
Connecticut (State)	7,500.00	6,006.86	395.80	24.93	45.55	449.83	203.85	136.89
Connecticut (Storrs)	7,500.00	7,500.00						
Delaware	15,000.00	11,715.10	501.39	6.35	48.86		1,361.78	195.62
Florida	15,000.00	12,576.68	256.41	24.16	106.91	98.13	330.46	276.66
Georgia	15,000.00	10,060.89	193.61	29.56	254.35	648.96	652.65	40.43
Idaho	15,000.00	10,080.87	2,235.88	8.00	187.32	122.65	698.87	604.23
Illinois	15,000.00	14,126.75	720.00		2.71		6.00	
Indiana	15,000.00	11,671.70	358.72	26.61	1.00		661.02	544.80
Iowa	15,000.00	8,858.12	1,857.48	71.81		314.81	1,038.47	672.88
Kansas	15,000.00	10,054.16	3,086.62	44.79	9.90	3.50	249.29	237.22
Kentucky	15,000.00	14,995.80	4.20					
Louisiana	15,000.00	10,999.94	575.00	47.70	66.52	286.49	707.51	157.35
Maine	15,000.00	13,933.87	349.00	58.35	21.15	33.76		16.85
Maryland	15,000.00	12,929.22	130.00	24.30	159.86	932.89	407.33	51.97
Massachusetts	15,000.00	14,947.50	52.50					
Michigan	15,000.00	14,554.20	445.80					
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	9,380.45	2,043.74		99.57	125.46		949.21
Missouri	15,000.00	7,242.61	1,557.79	47.18	112.80	137.35	299.61	912.70
Montana	15,000.00	11,439.88	1,707.66	1.63	66.39		633.01	184.25
Nebraska	15,000.00	14,978.60						15.90
Nevada	15,000.00	8,770.20	2,570.27	25.70	135.93	298.85	308.95	144.35
New Hampshire	15,000.00	11,460.00	1,257.31	22.58	51.60		589.17	222.02
New Jersey	15,000.00	12,165.00	374.03	35.25	3.72	637.50	601.80	176.82
New Mexico	15,000.00	8,535.68	2,986.64	88.35	341.42	339.87	791.84	385.43
New York (State)	1,500.00	1,500.00						
New York (Cornell)	13,500.00	10,277.77	2,710.00	16.00			473.64	17.59
North Carolina	15,000.00	15,000.00						
North Dakota	15,000.00	15,000.00						
Ohio	15,000.00	11,910.72	2,841.45				204.24	13.42
Oklahoma	15,000.00	13,140.00	1,074.62	.59		2.20	142.35	168.15
Oregon	15,000.00	13,372.50	256.67		40.21	33.34	601.78	363.21
Pennsylvania	15,000.00	10,884.74	192.47	43.51	53.29	12.38	1,174.35	42.23
Rhode Island	15,000.00	9,516.02	3,093.21	1.90	27.10	612.91	125.98	104.55
South Carolina	15,000.00	10,643.80	2,174.12	8.50	15.83	274.60	195.71	287.08
South Dakota	15,000.00	8,754.89	3,571.17	32.09	42.40		85.47	287.14
Tennessee	15,000.00	13,350.00	26.85	7.68	81.50	183.76	581.57	9.65
Texas	15,000.00	14,116.70	436.00		3.26			5.60
Utah	15,000.00	11,620.46	2,180.22	9.90	117.42		640.45	113.53
Vermont	15,000.00	10,080.00	2,753.24	103.16	7.27	44.58	262.64	188.92
Virginia	15,000.00	10,224.80	3,154.29		109.05		64.67	217.73
Washington	15,000.00	12,783.28	1,154.55	12.62	5.00		124.22	22.38
West Virginia	15,000.00	10,660.11	948.37	3.72		87.54	94.56	363.77
Wisconsin	15,000.00	8,210.00	3,459.05				172.06	364.51
Wyoming	15,000.00	11,310.66	430.97				669.30	145.09
Total	720,000.00	560,224.04	58,931.75	1,095.76	2,414.22	5,742.48	18,571.23	10,309.30

the act of March 16, 1906 (Adams Act), for the year ended June 30, 1922

Classified expenditures									
Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and repairs
----------	$817.55	$27.32	$493.20	$34.50	$718.08	$358.75	$392.39	----------	$615.96
----------	----------	----------	454.38	87.75	958.81	----------	632.55	----------	155.83
$457.15	340.83	----------	255.58	17.15	492.16	195.00	262.16	----------	12.39
----------	75.00	51.83	41.69	63.01	1,559.47	167.75	77.76	$8.00	178.85
----------	4.70	10.00	12.05	4.25	312.59	----------	337.70	----------	5.60
----------	76.41	----------	82.82	8.87	----------	----------	68.19	----------	----------
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
27.73	----------	32.19	14.60	77.85	875.59	----------	124.14	----------	18.80
279.63	----------	14.00	216.88	32.20	119.09	----------	642.19	----------	26.60
----------	2,303.02	138.28	.60	13.85	21.01	540.45	102.35	----------	----------
----------	140.40	8.50	202.40	13.03	185.41	16.80	489.64	----------	6.00
----------	140.54	----------	.75	----------	----------	3.25	----------	----------	----------
9.60	----------	15.20	382.43	12.18	232.82	880.90	203.02	----------	----------
22.31	957.03	----------	499.33	14.30	335.35	----------	214.36	----------	143.75
----------	650.46	----------	102.86	17.52	----------	75.44	11.32	----------	456.92
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
5.12	61.40	172.01	----------	168.51	1,508.70	----------	179.85	----------	63.90
----------	137.22	37.91	----------	----------	308.62	----------	103.27	----------	----------
----------	----------	2.88	2.95	12.91	279.54	----------	51.01	1.20	13.94
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	16.00	234.68	367.20	300.00	1,292.07	----------	183.42	----------	8.20
----------	3,412.82	5.00	71.79	12.50	845.53	251.34	----------	----------	90.98
----------	----------	----------	6.93	33.68	250.03	----------	676.54	----------	----------
----------	----------	----------	----------	----------	----------	5.50	----------	----------	----------
----------	572.40	28.45	28.10	22.10	283.65	1,493.80	317.25	----------	----------
----------	342.46	----------	28.22	3.61	612.01	----------	66.52	----------	344.50
14.97	360.00	176.50	131.84	44.15	226.05	----------	2.37	----------	50.00
44.68	167.70	13.65	145.53	48.16	476.07	330.00	4.96	----------	300.02
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	----------	----------	5.00	----------	----------	----------	----------	----------	----------
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	5.50	----------	----------	----------	----------	8.67	16.00	----------	----------
----------	340.00	.19	62.63	----------	----------	56.80	12.47	----------	----------
----------	----------	6.05	136.44	----------	147.97	----------	41.83	----------	----------
10.00	2.95	185.84	34.65	34.72	1,916.82	169.46	76.86	----------	165.73
----------	756.34	30.77	28.93	----------	180.30	46.00	----------	----------	475.99
259.56	----------	5.00	73.40	3.11	1,026.62	6.00	----------	----------	26.67
36.65	264.10	125.00	429.87	206.38	636.73	90.00	325.92	----------	112.19
----------	----------	78.53	60.57	33 93	280.75	----------	296.31	----------	8.90
----------	----------	----------	245.47	----------	191.40	----------	----------	----------	1.57
----------	----------	----------	1.50	125.39	----------	----------	191.13	----------	----------
----------	71.60	7.34	23.38	----------	926.76	152.50	276.61	.80	101.20
120.65	746.82	----------	76.71	1.20	54.45	----------	92.08	----------	137.55
----------	----------	----------	122.41	3.67	516.57	66.00	189.30	----------	----------
2.75	508.10	----------	93.71	----------	1,674.85	----------	562.52	----------	----------
----------	2,536.60	----------	6.75	----------	193.14	48.00	9.89	----------	----------
----------	427.54	6.06	221.75	742.35	126.49	839.25	80.54	----------	----------
1,290.80	16,235.49	1,413.18	5,165.30	2,192.83	19,765.50	5,801.66	7,314.42	10.00	3,522.04

TABLE 6.—*Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, and March 16, 1906*

State or Territory	Hatch Act		Adams Act	
	1888–1921	1922	1906–1921	1922
Alabama	$508,956.42	$15,000.00	$206,619.89	$15,000.00
Arizona	474,803.10	15,000.00	209,955.61	15,000.00
Arkansas	508,139.12	15,000.00	209,900.00	15,000.00
California	510,000.00	15,000.00	209,926.84	15,000.00
Colorado	509,718.82	15,000.00	208,638.93	15,000.00
Connecticut	510,000.00	15,000.00	210,000.00	15,000.00
Dakota Territory	56,250.00			
Delaware	508,382.87	15,000.00	205,475.12	15,000.00
Florida	509,966.06	15,000.00	209,996.06	15,000.00
Georgia	505,593.43	15,000.00	197,092.87	15,000.00
Idaho	434,324.13	15,000.00	205,842.22	15,000.00
Illinois	509,564.95	15,000.00	209,851.62	15,000.00
Indiana	509,901.19	15,000.00	210,000.00	15,000.00
Iowa	510,000.00	15,000.00	210,000.00	15,000.00
Kansas	509,995.00	15,000.00	210,000.00	15,000.00
Kentucky	509,996.57	15,000.00	210,000.00	15,000.00
Louisiana	510,000.00	15,000.00	210,000.00	15,000.00
Maine	509,999.62	15,000.00	210,000.00	15,000.00
Maryland	509,967.40	15,000.00	209,236.48	15,000.00
Massachusetts	509,617.70	15,000.00	210,000.00	15,000.00
Michigan	509,676.10	15,000.00	206,341.20	15,000.00
Minnesota	509,917.78	15,000.00	209,345.00	15,000.00
Mississippi	510,000.00	15,000.00	210,000.00	15,000.00
Missouri	505,097.24	15,000.00	209,999.90	15,000.00
Montana	420,000.00	15,000.00	207,417.04	15,000.00
Nebraska	509,932.16	15,000.00	210,000.00	15,000.00
Nevada	509,214.32	15,000.00	208,180.28	15,000.00
New Hampshire	510,000.00	15,000.00	210,000.00	15,000.00
New Jersey	509,949.97	15,000.00	209,392.06	15,000.00
New Mexico	474,509.05	15,000.00	210,000.00	15,000.00
New York	509,765.43	14,992.16	209,463.25	14,999.76
North Carolina	510,000.00	15,000.00	195,000.00	15,000.00
North Dakota	451,502.26	15,000.00	209,638.85	15,000.00
Ohio	510,000.00	15,000.00	208,514.02	15,000.00
Oklahoma	434,568.96	15,000.00	191,360.56	15,000.00
Oregon	495,156.64	15,000.00	205,000.00	15,000.00
Pennsylvania	509,967.43	15,000.00	209,995.41	15,000.00
Rhode Island	510,000.00	15,000.00	207,464.20	15,000.00
South Carolina	509,542.15	15,000.00	208,460.12	15,000.00
South Dakota	453,250.00	15,000.00	205,000.00	15,000.00
Tennessee	510,000.00	15,000.00	210,000.00	15,000.00
Texas	510,000.00	15,000.00	207,592.26	15,000.00
Utah	375,000.00	15,000.00	209,821.94	15,000.00
Vermont	510,000.00	15,000.00	210,000.00	15,000.00
Virginia	507,824.12	15,000.00	209,949.01	15,000.00
Washington	447,102.65	15,000.00	206,080.11	15,000.00
West Virginia	509,968.71	15,000.00	207,859.12	15,000.00
Wisconsin	510,000.00	15,000.00	210,000.00	15,000.00
Wyoming	495,000.00	15,000.00	210,000.00	15,000.00
Total	23,862,121.35	719,992.16	9,984,409.97	719,999.76

PUBLICATIONS

The publications of the stations are steadily increasing in volume and diversity of subject matter. The list here given of bulletins, circulars, and reports received by the Office of Experiment Stations during the year 1921-22, includes 118 publications which deal with animal husbandry subjects including dairying, 75 with field crops, 61 with horticulture, 55 with entomology and zoology, 38 with soils and fertilizers, 34 with plant diseases, 30 with agricultural economics, 18 with veterinary medicine, 13 with agricultural engineering, and lesser numbers with other subjects. In addition, there are 58 entries under annual reports and 41 under regulatory publications.

It should be noted that this list does not include press bulletins and other fugitive publications, or articles published in scientific journals. To an increasing extent station investigators are publishing the more technical results of their work in various scientific journals. Such publication has reached considerable proportions and represents a very important part of the scientific output of the stations.

LIST OF PUBLICATIONS OF THE EXPERIMENT STATIONS DURING THE FISCAL YEAR 1922

AGRICULTURAL CHEMISTRY

Adsorption at liquid-vapor and liquid-liquid interfaces and some related phenomena. H. H. King. (Kansas Sta. Tech. Bul. 9, pp. 41, figs. 7.)
Rate and extent of solubility of minerals and rocks under different treatments and conditions. G. J. Bouyoucos. (Michigan Sta. Tech. Bul. 50, pp. 32.)
A chemical study of broomcorn and broomcorn silage. C. T. Dowell and W. G. Friedemann. (Oklahoma Sta. Bul. 135, pp. 7.)
A method for determining adulterants in butterfat. G. Spitzer and W. F. Epple. (Indiana Sta. Bul. 254, pp. 16, fig. 1.)

BOTANY AND PLANT PHYSIOLOGY

Some physical and chemical studies of certain clones and sibs of brome grass L. R. Waldron. (North Dakota Sta. Research Bul. 152, pp. 28, pls. 3, figs. 3.)
Physical characters and some of their correlations in *Bromus inermis*. L. R. Waldron. (North Dakota Sta. Research Bul. 153, pp. 31, figs. 5.)
Studies in pollen, with special reference to longevity. H. E. Knowlton. (New York Cornell Sta. Mem. 52, pp. 747–793.)
The seasonal march of the climatic conditions of a greenhouse, as related to plant growth. E. S. Johnston. (Maryland Sta. Bul. 245, pp. 41–98, figs. 7.)
The effects of shading some horticultural plants. J. H. Gourley and G. T. Nightingale. (New Hampshire Sta. Tech. Bul. 18, pp. 22, figs. 19.)
Liberation of organic matter by roots of growing plants. T. L. Lyon and J. K. Wilson. (New York Cornell Sta. Mem. 40, pp. 44, figs. 9.)
A study of the influence of physical soil factors and of various fertilizer chemicals on the growth of the carnation plant. F. R. Pember and G. E. Adams. (Rhode Island Sta. Bul. 187, pp. 94.)
An investigation of sulphur as a plant food. G. A. Olsen and J. L. St. John. (Washington Sta. Tech. Bul. 165, pp. 69, figs. 11.)
Titanium, barium, strontium, and lithium in certain plants. W. P. Headden. (Colorado Sta. Bul. 267, pp. 20.)
Investigations on the hardening process in vegetable plants. J. T. Rosa, jr. (Missouri Sta. Research Bul. 48, pp. 97, figs. 16.)
Respiration of shelled corn. C. H. Bailey. (Minnesota Sta. Tech. Bul. 3, pp. 44, figs. 12.)
Common weeds and their control. J. G. Fiske. (New Jersey Stas. Circ. 125, pp. 19, figs. 14.)
Nineteen noxious weeds of Indiana.—Description, eradication, and control of the nineteen weeds designated as noxious in the Indiana seed law. A. A. Hansen. (Indiana Sta. Circ. 106, pp. 32, figs. 20.)
The blueweed and its eradication. R. E. Karper. (Texas Sta. Bul. 292, pp. 13, figs. 5.)

GENETICS

The genetic relations of plant colors in maize. R. A. Emerson. (New York Cornell Sta. Mem. 39, pp. 156, pls. 11.)
The inheritance of salmon silk color in maize. E. G. Anderson. (New York Cornell Sta. Mem. 48, pp. 539–554, pls. 4.)

BACTERIOLOGY

Studies on the physiology of some plant pathogenic bacteria. (North Carolina Sta. Tech. Bul. 20, pp. 47, fig. 1.)

The use of agar slants in detecting fermentation; Rose bengal as a general bacterial stain; A modification and new application of the Gram stain. H. J. Conn and G. J. Hucker. (New York State Sta. Tech. Bul. 84, pp. 9.)

The use of various culture media in characterizing actinomycetes. H. J. Conn. (New York State Sta. Tech. Bul. 83, pp. 26.)

METEOROLOGY

Meteorological observations at the Massachusetts Agricultural Experiment Station. J. E. Ostrander et al. (Massachusetts Sta. Met. Buls. 390–401, pp. 4 each.)

Ohio weather for 1920. W. H. Alexander and C. A. Patton. (Ohio Sta. Bul. 352, pp. 261–354, figs. 63.)

SOILS

Soil analysis and soil and plant interrelations. D. R. Hoagland. (California Sta. Circ. 235, pp. 7.)

Studies on the reactions between soils and various chemical compounds. C. H. Spurway. (Michigan Sta. Tech. Bul. 51, pp. 29.)

A comparison of the calcium content of some virgin and cultivated soils of Kentucky by an improved method for the estimation of this element. O. M. Shedd. (Kentucky Sta. Research Bul. 236, pp. 305–330.)

The removal of mineral plant food by natural drainage waters. J. S. McHargue and A. M. Peter. (Kentucky Sta. Research Bul. 237, pp. 333–362, fig. 1.)

Availability of potash in some soil-forming minerals. G. S. Fraps. (Texas Sta. Bul. 284, pp. 16, figs. 3.)

Fallow experiments in south central Montana.—Results from the Experimental Dry Farm, Huntley, Mont. A. E. Seemans. (Montana Sta. Bul. 142, pp. 24.)

Summer tillage in Montana. C. McKee. (Montana Sta. Circ. 102, pp. 4.)

Investigations in dry farm tillage. M. A. McCall and H. F. Holtz. (Washington Sta. Bul. 164, pp. 51 + [5], figs. 12.)

Relation of soil nitrogen, nitrification and ammonification to pot experiments. G. S. Fraps. (Texas Sta. Bul. 283, pp. 51, figs. 3.)

Solvent action of nitrification and sulfofication. J. W. Ames. (Ohio Sta. Bul. 351, pp. 223–257.)

The chemical composition of the soils of the Belvidere area in New Jersey. A. W. Blair and H. C. McLean. (New Jersey Stas. Bul. 362, pp. 16, figs. 2.)

The chemical composition of the soils of the Millville area in New Jersey. A. W. Blair and H. C. McLean. (New Jersey Stas. Bul. 366, pp. 15, figs. 4.)

Composition of some soils from the Chautauqua County grape belt. R. C. Collison. (New York State Sta. Tech. Bul. 85, pp. 15, fig. 1.)

Peoria County soils. J. G. Mosier, S. V. Holt, E. Van Alstine, and F. W. Garrett. (Illinois Sta. Soil Rpt. 19, pp. [1] + 57, pls. 2, figs. 8.)

Bureau County soils. J. G. Mosier, S. V. Holt, E. Van Alstine, and F. W. Garrett. (Illinois Sta. Soil Rpt. 20, pp. 72, pls. 3, figs. 12.)

McHenry County soils. J. G. Mosier, R. W. Dickenson, H. W. Stewart, E. Van Alstine, and H. J. Snider. (Illinois Sta. Soil Rpt. 21, pp. 50, pls. 2, figs. 10.)

Iroquois County soils. J. G. Mosier, S. V. Holt, E. Van Alstine, and H. J. Snider. (Illinois Sta. Soil Rpt. 22, pp. 60, pls. 4, figs. 7.)

Soil survey of Iowa—Wayne County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 19, pp. 56, pl. 1, figs. 15.)

Soil survey of Iowa—Hamilton County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 20, pp. 54, pl. 1, figs. 11.)

Soil survey of Iowa—Louisa County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 21, pp. 70, pl. 1, figs. 12.)

The silt loam soils of eastern Washington and their management. F. J. Sievers and H. F. Holtz. (Washington Sta. Bul. 166, pp. 62, figs. 25.)

Preliminary report on the management of Willamette Valley soils. (Oregon Sta. Bul. 185, pp. 12, fig. 1.)

Lysimeter experiments.—II, Records for tanks 13 to 16 during the years 1913 to 1917, inclusive. T. A. Lyon and J. A. Bizzell. (New York Cornell Sta. Mem. 41, pp. 45–93.)
Guide to soil experiment fields (Missousi Sta. Dept. Guide 1, pp. 12, pl. 1, figs. 2.)
Manual of the principal soils of Missouri. M. F. Miller and H. H. Krusekopf. (Missouri Sta. [Pamphlet], pp. 15, fig. 1.)

FERTILIZERS

Fertilizer experiments. C. P. Blackwell and T. S. Buie. (South Carolina Sta. Bul. 209, pp. [77], figs. 52.)
The comparative value of different forms of lime. A. G. McCall. (Maryland Sta. Bul. 242, pp. 157–166, fig. 1.)
Liming with high magnesium v. high calcium limes. B. L. Hartwell. (Rhode Island Sta. Bul. 186, pp. 19.)
The effect of rock phosphate upon the corn possibility of the phosphoric acid of the soil. G. S. Fraps. (Texas Sta. Bul. 289, pp. 17, figs. 5.)
Thirty years' experience with sulfate of ammonia. F. W. Morse. (Massachusetts Sta. Bul. 204, pp. 83–98, pls. 2.)
Availability of some nitrogenous and phosphatic materials. G. S. Fraps. (Texas Sta. Bul. 287, pp. 16, figs. 2.)
Decomposition of green manures at different stages of growth. T. L. Martin. (New York Cornell Sta. Bul. 406, pp. 135–169, figs. 10.)
Sweet clover for nitrate production. A. L. Whiting and T. E. Richmond. (Illinois Sta. Bul. 233, pp. 253–267, fig. 1.)
The substitution of stable manure by fertilizers, green manures, and peat. B. L. Hartwell and F. K. Crandall. (Rhode Island Sta. Bul. 188, pp. 23, fig. 1.)
The use of fertilizers on dairy farms. A. R. Whitson and G. Richards. (Wisconsin Sta. Bul. 341, pp. 24, figs. 4.)
Fertilizers for Maryland soils. A. G. McCall. (Maryland Sta. Bul. 247, pp. 117–151, figs, 7.)
Changes in the composition and cost of fertilizers in New York from 1914 to 1921. L. L. Van Slyke. (New York State Sta. Bul. 493, pp. 12.)
Testing fertilizers for Missouri farmers, 1921. F. B. Mumford. (Missouri Sta. Bul. 192, pp. 70, fig. 1.)

FIELD CROPS

Alfalfa.

Alfalfa experiment. M. A. Beeson, A. Daane, and D. R. Johnson. (Oklahoma Sta. Bul. 138, pp. 18, figs. 3.)
Alfalfa culture (Holly Springs Branch Station). C. T. Ames. (Mississippi Sta. Circ. 43, pp. 4.)
Irrigation of alfalfa. W. L. Powers and W. W. Johnston. (Oregon Sta. Bul. 189, pp. 36. figs. 22.)
Alfalfa production under irrigation. G. Stewart. (Utah Sta. Circ. 45, pp. 48, figs. 14.)
Fertilizers for alfalfa in eastern Kansas. L. E. Call, R. I. Throckmorton, C. C. Cunningham, and B. S. Wilson. (Kansas Sta. Bul. 226, pp. 30, figs. 3.)

Corn.

Production of new strains of corn for New York. C. H. Myers, H. H. Love, and F. P. Bussell. (New York Cornell Sta. Bul. 408, pp. 205–268, figs. 12.)
Characters connected with the yield of the corn plant. W. C. Etheridge. (Missouri Sta. Research Bul. 46, pp. 17, fig.1.)
Correlation between the yields and prolificness of corn varieties grown in Mississippi. H. B. Brown and J. F. O'Kelly. (Mississippi Sta. Circ. 40, pp. 4, figs. 2.)
The effect of a varying supply of nutrients upon the character and composition of the maize plant at different periods of growth. F. L. Duley and M. F. Miller. (Missouri Sta. Research Bul. 42, pp. 66, figs. 25.)
Varieties of corn in Kansas. C. C. Cunningham and B. S. Wilson. (Kansas Sta. Bul. 227, pp. 40, figs. 9.)
Corn in Missouri.—II, Field methods that increase the corn crop. C. A. Helm. (Missouri Sta. Bul. 185, pp. 20, figs. 4.)

Corn—Continued.

Planting rates and spacing of corn, with tables for practical use. C. A. Mooers. (Tennessee Sta. Bul. 124, pp. 31–43.)
Corn experiments in south central Montana.—Results from the experimental dry farm, Huntley, Montana. A. E. Seemans. (Montana Sta. Bul. 140, pp. 24, figs. 7.)
Corn growing in New Jersey. G. W. Musgrave. (New Jersey Stas. Circ. 128, pp. 22, figs. 13.)

Cotton.

Cotton experiments. H. B. Brown and J. F. O'Kelly. (Mississippi Sta. Bul. 205, pp. 16, figs. 2.)
Cotton variety experiments, 1912–1920, Substation No. 7, Spur, Tex. G. F. Freeman and R. E. Dickson. (Texas Sta. Bul. 288, pp. 17.)
Why not plant home-grown cotton seed? H. B. Brown. (Mississippi Sta. Circ. 37, pp. 3.)

Forage Crops—Clovers—Grasses.

Hubam clover. F. S. Wilkins. (Iowa Sta. Circ. 76, pp. 16, figs. 7.)
Sweet clover in Arizona. S. P. Clark. (Arizona Sta. Circ. 34, pp. 7.)
Sweet clover. R. K. Bonnett and H. W. Hulbert. (Idaho Sta. Circ. 22, pp. 14, figs. 3.)
Sweet clover. C. R. McGee. (Michigan Sta. Spec. Bul. 113, pp. 14, figs. 6.)
Sweet clover. C. R. McGee. (Michigan Sta. Circ. 46, pp. 4, figs. 2.)
The pigeon pea (*Cajanus indicus*): Its culture and utilization in Hawaii. F. G. Krauss. (Hawaii Sta. Bul. 46, pp. 23, pls. 5, fig. 1.)
Para and paspalum: Two introduced grasses of Guam. G. Briggs. (Guam Sta. Bul. 1, pp. 44, pls. 6.)
Sudan grass in Arizona. R. S. Hawkins. (Arizona Sta. Circ. 35, pp. 5, figs. 2.)
Rhodes grass in Arizona. S. P. Clark. (Arizona Sta. Circ. 36, pp. 3.)
Sunflowers, their culture and use. A. F. Vass. (Wyoming Sta. Bul. 129, pp. 75–107, figs. 2.)
The culture and feeding of Russian sunflowers. G. R. Quesenberry, C. C. Cunningham, and L. Foster. (New Mexico Sta. Bul. 126, pp. 20, figs. 6.)
Management of meadows and pastures. G. L. Shuster. (Delaware Sta. Bul. 130, pp. 16, figs. 3.)

Potatoes.

Potato growing in Iowa as affected by temperature. A. T. Erwin and R. A. Rudnick. (Iowa Sta. Bul. 206, pp. 71–84, figs. 10.)
Further studies on the effect of missing hills in potato fields and on the variation in the yield of potato plants from halves of the same seed tuber. F. C. Stewart. (New York State Sta. Bul. 489, pp. 52, figs. 3.)
Some phases of breeding work and seed production of Irish potatoes. W. J. Young. (South Carolina Sta. Bul. 210, pp. 20, figs. 4.)
Seed potato improvement. G. R. Hyslop. (Oregon Sta. Circ. 25, pp. 8, fig. 1.)
Seed potatoes for Connecticut. W. L. Slate, jr., and B. A. Brown. (Connecticut Storrs Sta. Bul. 107, pp. 51–56, fig. 1.)
Seed studies with Irish potatoes. J. T. Rosa, jr. (Missouri Sta. Bul. 191, pp. 32, figs. 5.)
Seed potatoes for better yields. J. T. Rosa, jr. (Missouri Sta. Circ. 106, pp. 8, figs. 3.)
Potato seed experiments: Whole small tubers *v.* pieces of large tubers of the same plant. F. C. Stewart. (New York State Sta. Bul. 491, pp. 30.)
Do whole small potatoes make good seed? J. D. Luckett and F. C. Stewart. (New York State Sta. Bul. 491, pop. ed., pp. 7, fig. 1.)
Potato growing in New Jersey. W. H. Martin. (New Jersey Stas. Circ. 140, pp. 31, figs. 13.)
Potatoes in South Dakota. A. T. Evans, G. Jansen, and M. Fowlds. (South Dakota Sta. Bul. 196, pp. 373–415, figs. 13.)

Sweet potatoes.

Sweet potatoes. (North Carolina Sta. Farmers' Market Bul., 9 (1922), No. 49, pp. 8.)

Sweet potatoes—Continued.

Sweet potato fertilizer experiments at Substation No. 2, Troup. W. S. Hotchkiss. (Texas Sta. Bul. 277, pp. 7, fig. 1.)
The sweet potato for south Mississippi. E. B. Ferris and F. B. Richardson. (Mississippi Sta. Bul. 206, pp. 20.)
Sweet potato storage in Delaware. T. F. Manns. (Delaware Sta. Bul. 127, pp. 64, figs. 47.)

Sorghum.

Shelling percentage in grain sorghum. A. B. Conner and R. E. Karper. (Texas Sta. Bul. 294, pp. 11, figs. 2.)
Type and variability in Kafir. A. B. Conner and R. E. Karper. (Texas Sta. Bul. 279, pp. 14, figs. 6.)
Hegari in Arizona. G. E. Thompson. (Arizona Sta. Circ. 33, pp. 4, fig. 1.)

Soybeans.

Soybeans. E. J. Kinney and C. Roberts. (Kentucky Sta. Bul. 232, pp. 25–58, fig. 1.)
Productive methods for soybeans in Missouri. W. C. Etheridge and C. A. Helm. (Missouri Sta. Bul. 195, pp. 33, figs. 13.
Soybeans in South Dakota. A. T. Evans and M. Fowlds. (South Dakota Sta. Bul. 193, pp. 317–324.)

Sugar-producing plants.

Sugar beet growing in Michigan. J. F. Cox and E. B. Hill. (Michigan Sta. Spec. Bul. 106, pp. 23, figs. 20.)
Sugar cane for sirup making. E. B. Ferris. (Mississippi Sta. Bul. 199, pp. 20.)
Sugar cane in St. Croix. L. Smith. (Virgin Islands Sta. Bul. 2, pp. 23, pls. 2, fig. 1.)

Tobacco.

Strains of Standup White Burley tobacco resistant to root rot. W. D. Valleau and E. J. Kinney. (Kentucky Sta. Circ. 28, pp. 16, figs. 6.)
Tobacco in Wisconsin. J. Johnson and C. M. Slagg. (Wisconsin Sta. Bul. 337, pp. 36, figs. 21.)

Wheat.

Varietal trials with spring wheat in North Dakota. T. E. Stoa. (North Dakota Sta. Bul. 149, pp. 55, pls. 2, fig. 1.)
Winter wheat in North Dakota. L. R. Waldron. (North Dakota Sta. Bul. 151, pp. 8.)
Winter wheat in western Nebraska. L. L. Zook. (Nebraska Sta. Bul. 179, pp. 37, figs. 9.)
Acme wheat. A. M. Hume. (South Dakota Sta. Bul. 194, pp. 325–356, figs. 3.)
Productive methods for wheat in Missouri. C. A. Helm and L. J. Stadler. (Missouri Sta. Bul. 188, pp. 40, figs. 8.)
The 1920 wheat, oats, and corn yields from soil experiment fields in Illinois. (Illinois Sta. Circ. 246, pp. 4.)
Garlic and other factors influencing grades of wheat. J. E. Metzger. (Maryland Sta. Bul. 246, pp. 99–116, figs. 3.)

Other cereals.

A classification of the cultivated varieties of barley. R. G. Wiggans. (New York Cornell Sta. Mem. 46, pp. 365–456, pls. 5, figs. 22.)
Desirable qualities of California barley for export. J. W. Gilmore and L. J. Fletcher. (California Sta. Circ. 246, pp. 11, fig. 1.)
Productive methods for oats in Missouri. C. A. Helm and L. J. Stadler. (Missouri Sta. Circ. 105, pp. 16, fig. 1.)
Kanota, an early oat for Kansas. S. C. Salmon and J. H. Parker. (Kansas Sta. Circ. 91, pp. 13, figs. 3.)
Wisconsin oats. B. D. Leith and E. J. Delwiche. (Wisconsin Sta. Bul. 340, pp. 30, figs. 8.)
Rosen rye. F. A. Spragg. (Michigan Sta. Spec. Bul. 105, pp. 11, figs. 8.)

Miscellaneous.

Dependable Michigan crop varieties. J. F. Cox. (Michigan Sta. Spec. Bul. 109. pp. 19, figs. 11.)
Crop rotations for Missouri soils. R. R. Hudelson and C. A. Helm. (Missouri Sta. Bul. 183, pp. 27, figs. 11.)
Thirty years of field experiments with crop rotation, manure, and feritlizers. M. F. Miller and R. R. Hudelson. (Missouri Sta. Bul. 182, pp. 43, figs. 11.)
Fertilizer requirements of rotations, including corn, potatoes, rye, and hay. B. L. Hartwell and S. C. Damon. (Rhode Island Sta. Bul. 185, pp. 39.)
Grain mixtures and root crops under irrigation. P. V. Cardon. (Montana Sta. Bul. 143, pp. 14.)
Dry farm crop production in eastern New Mexico. J. C. Cole. (New Mexico Sta. Bul. 130, pp. 32, figs. 5.)
Experiments in field plat technic for the preliminary determination of comparative yields in the small grains. L. J. Stadler. (Missouri Sta. Research Bul. 49, pp. 78, figs. 4.)

HORTICULTURE

Fruits—General.

Localization of the factors determining fruit bud formation. H. D. Hooker, jr., and F. C. Bradford. (Missouri Sta. Research Bul. 47, pp. 19.)
Studies in orchard management. K. Sax. (Maine Sta. Bul. 298, pp. 53–84, fig. 1.)
Orchard soil management and fertilization. O. M. Morris and R. Larsen. (Washington Sta. Pop. Bul. 121, pp. 23, figs. 2.)
Central wire bracing for fruit trees. L. C. Barnard. (California Sta. Circ. 244, pp. 10, figs. 8.)
Orchard survey of the northeastern district of Colorado. E. P. Sandsten and C. M. Tompkins. (Colorado Sta. Bul. 272, pp. 28.)
Orchard survey of the Arkansas Valley district. E. P. Sandsten and C. M. Tompkins. (Colorado Sta. Bul. 273, pp. 24.)

Apples.

Studies in apple pollination. O. M. Morris. (Washington Sta. Bul. 163, pp. 32, figs. 6.)
Certain responses of apple trees to nitrogen applications of different kinds and at different seasons. H. D. Hooker, jr. (Missouri Sta. Research Bul. 50, pp. 18.)
First 15 years of 40-variety apple orchard. Apple selection from high and low yielding parent trees. M. B. Cummings. (Vermont Sta. Bul. 221, pp. 38, pls. 4, figs. 2.)
Hood River apple orchard management with special reference to yields, grades, and value of fruits. G. G. Brown. (Oregon Sta. Bul. 181, pp. 36, figs. 7.)
Apples in north Mississippi (Holly Springs Branch Station). J. C. C. Price and C. T. Ames. (Mississippi Sta. Circ. 41, figs. 2.)

Grapes and small fruits.

Grapes. F. W. Faurot. (Missouri Sta. Circ. 20, pp. 28, figs. 12.)
The home vineyard. L. O. Bonnet. (California Sta. Circ. 231, pp. 12, figs. 4.)
Replacing missing vines. F. T. Bioletti. (California Sta. Circ. 249, pp. 4, fig. 1.)
Vine pruning systems. F. T. Bioletti. (California Sta. Circ. 245, pp. 4, figs. 3.)
Cordon pruning. F. T. Bioletti. (California Sta. Circ. 229, pp. 14, figs. 9.)
Vineyard irrigation in arid climates. F. T. Bioletti. (California Sta. Circ. 228, pp. 4.)
Phylloxera-resistant stocks. F. T. Bioletti, F. C. H. Flossfeder, and A. E. Way. (California Sta. Bul. 331, pp. 79–139, figs. 11.)
Grape production and distribution in western Iowa. T. J. Maney. (Iowa Sta. Bul. 199, pp. 376–399, figs. 10.)

Grapes and small fruits—Continued.

Grapes in Mississippi. J. C. C. Price. (Mississippi Sta. Circ. 44, pp. 4, figs. 3.)
Small fruit growing in Missouri. H. G. Swartwout. (Missouri Sta. Bul. 184, pp. 27, figs. 6.)
Blackberries of New England.—Genetic status of the plants. A. K. Petersen. (Vermont Sta. Bul. 218, pp. 34, pls. 19.)

Miscellaneous fruits.

The apricot in California. W. L. Howard. (California Sta. Circ. 238, pp 53, figs. 8.)
Harvesting and handling apricots and plums for eastern shipment. W. P. Duruz. (California Sta. Circ. 239, pp. 24, figs. 21.)
Harvesting and handling California cherries for eastern shipment. W. P. Duruz. (California Sta. Circ. 232, pp. 19, figs. 14.)
A new test for maturity of the pear.—Pear harvesting and storage investigations (third report). A. E. Murneek. (Oregon Sta. Bul. 186, pp. 28, figs. 9.)
Harvesting and handling California pears for eastern shipment. W. P. Duruz. (California Sta. Circ. 240, pp. 19, figs. 10.)
Harvesting and handling California peaches for eastern shipment. W. P. Duruz. (California Sta. Circ. 241, pp. 21, figs. 13.)
Prune growing in California. A. H. Hendrickson. (California Sta. Bul. 328, pp. 38, figs. 12.)
The olive in Arizona. F. J. Crider. (Arizona Sta. Bul. 94, pp. 399–528, figs. 20.)
Some factors affecting the quality of ripe olives sterilized at high temperatures. W. V. Cruess. (California Sta. Bul. 333, pp. 221–231, figs. 2.)

Fruit products.

Dehydration of fruits. W. V. Cruess and A. W. Christie. (California Sta. Bul. 330, pp. 47–77, figs. 2.)
Some factors of dehydrater efficiency. W. V. Cruess and A. W. Christie. (California Sta. Bul. 337, pp. 277–298, figs. 8.)
Marmalade juice and jelly juice from citrus fruits. W. V. Cruess and L. Singh. (California Sta. Circ. 243, pp. 8, figs. 3.)

Walnuts.

Walnut culture in California. L. D. Batchelor. (California Sta. Bul. 332, pp. 139–218, figs. 33.)
Winter injury to young walnut trees during 1921–1922. L. D. Batchelor. (California Sta. Circ. 234, pp. 5, figs. 3.)

Vegetables.

The home vegetable garden. R. A. McGinty. (Colorado Sta. Bul. 276, pp. 36, figs. 5.)
The home vegetable garden as a business proposition. J. T. Rosa, jr. (Missouri Sta. Bul. 193, pp. 16, figs. 8.)
Vegetable gardening in Oregon. A. G. B. Bouquet. (Oregon Sta. Circ. 23, pp. 43, figs. 12.)
The Robust bean. F. A. Sprague and E. E. Down. (Michigan Sta. Spec. Bul. 108, pp. 11, figs. 5.)
Growing head lettuce in Idaho. C. C. Vincent. (Idaho Sta. Circ. 21, pp. 11, figs. 4.)
Pimento and bell peppers. H. P. Stuckey and J. A. McClintock. (Georgia Sta. Bul. 140, pp. 31–43, figs. 6.)
Breeding mosaic-resistant spinach and notes on malnutrition. L. B. Smith. (Virginia Truck Sta. Bul. 31–32, pp. 135–160, figs. 5.)
Yield and quality in Hubbard squash. M. B. Cummings and W. C. Stone. (Vermont Sta. Bul. 222, pp. 48, pls. 2, figs. 7.)
Better methods of tomato production. J. T. Rosa, jr. (Missouri Sta. Bul. 194, pp. 24, figs. 9.)
Tests of the wilt resistance of different tomato varieties. C. W. Edgerton and C. C. Moreland. (Louisiana Stas. Bul. 184, pp. 24, figs. 8.)
Truck crop investigations.—Relation of pressure to effectiveness in spraying tomatoes. L. B. Smith and H. H. Zimmerley. (Virginia Truck Sta. Bul. 33–34, pp. 163–190, figs. 10.)

Vegetables—Continued.

Canning factory tomatoes. H. D. Brown. (Indiana Sta. Bul. 259, pp. 20, figs. 8.)

Spraying, dusting, and fumigating.

Spray and practice outline. C. P. Halligan, R. H. Pettit, and G. H. Coons. (Michigan Sta. Spec. Bul. 114, pp. 28, figs. 9.)
Dusting and spraying experiments of 1920 and 1921. W. C. Dutton and S. Johnston. (Michigan Sta. Spec. Bul. 115, pp. 54, figs. 24.)
Spray calendar for apples and quinces. T. J. Headlee, M. T. Cook, and A. J. Farley. (New Jersey Stas. Circ. 132, pp. 4, figs. 3.)
Spray calendar for peaches. T. J. Headlee, M. T. Cook, and A. J. Farley. (New Jersey Stas. Circ. 133, pp. 4, figs. 3.)
Spray calendar for pears. T. J. Headlee, M. T. Cook, and A. J. Farley. (New Jersey Stas. Circ. 134, pp. 4, figs. 3.)
Spray calendar for cherries. T. J. Headlee, M. T. Cook, and A. J. Farley. (New Jersey Stas. Circ. 135, pp. 3, figs. 2.)
Spray calendar for grapes. A. J. Farley, M. T. Cook, and T. J. Headlee. (New Jersey Stas. Circ. 136, pp. 3, fig. 1.)
Selection and treatment of waters for spraying purposes with especial reference to Santa Clara Valley. E. R. DeOng. (California Sta. Bul. 338, pp. 301–314, figs. 2.)
Experiments in dusting *v.* spraying on apples and peaches in Connecticut in 1921. W. E. Britton, M. P. Zappe, and E. M. Stoddard. (Connecticut State Sta. Bul. 235, pp. 207–226, pls. 6, figs. 5.)
Spreading and adherence of arsenical sprays. W. Moore. (Minnesota Sta. Tech. Bul. 2, pp. 50, fig. 1.)
Dusting vegetable crops. H. H. Zimmerley, F. W. Geise, and C. R. Willey. (Virginia Truck Sta. Bul. 35–36, pp. 193–208, figs. 6.)
Laboratory studies of the toxicity of some sulphur fungicides. W. L. Doran. (New Hampshire Sta. Tech. Bul. 19, pp. 11.)
A study of the distribution of hydrocyanic acid gas in greenhouse fumigation. W. H. W. Komp. (New Jersey Stas. Bul. 355, pp. 22, figs. 15.)

FORESTRY

Eccentric growth and the formation of redwood in the main stem of conifers. G. P. Burns. (Vermont Sta. Bul. 219, pp. 16, pls. 4, figs. 10.)
Preliminary volume tables for second-growth redwood. D. Bruce. (California Sta. Bul. 334, pp. 235–237.)
A white fir volume table. D. Bruce. (California Sta. Bul. 329, pp. 39–45.)
An investigation of the seed of the silver maple (*Acer saccharinum*). R. J. Anderson and W. L. Kulp. (New York State Sta. Tech. Bul. 81, pp. 20.)
Growth of oak in the Ozarks. F. Dunlap. (Missouri Sta. Research Bul. 41, pp. 28, figs. 7.)
Precipitation and the growth of oaks at Columbia, Missouri. W. J. Robbins. (Missouri Sta. Research Bul. 44, pp. 21, pl. 1, figs. 3.)
Working plan for a communal forest for the town of Ithaca, New York. J. S. Everitt. (New York Cornell Sta. Bul. 404, pp. 51–99, figs. 15.)
Forest planting in Michigan. A. K. Chittenden. (Michigan Sta. Spec. Bul. 103, pp. 16, figs. 5.)

PLANT DISEASES

Field-crop diseases.

Dry rot of corn. I. E. Melhus and L. W. Durrell. (Iowa Sta. Circ. 78, pp. 8, figs. 6.)
Corn root rot diseases. T. F. Manns and J. F. Adams. (Delaware Sta. Bul. 128, pp. 24, figs. 15.)
A new Ascochyta disease of cotton. J. A. Elliott. (Arkansas Sta. Tech. Bul. 178, pp. 18, figs. 5.)
Comparative resistance of varieties of oats to crown and stem rusts. L. W. Durrell and J. H. Parker. (Iowa Sta. Research Bul. 62, pp. 25-56 + [4], figs. 13.)
Potato diseases in Oregon and their control. M. B. McKay. (Oregon Sta. Circ. 24, pp. 52, figs. 38.)
Potato scab and methods for its control. W. H. Martin. (New Jersey Stas. Bul. 131, pp. 12, figs. 3.)

Field-crop diseases—Continued.

The mosaic disease of the Irish potato and the use of certified potato seed. C. W. Edgerton and G. L. Tiebout. (Louisiana Stas. Bul. 181, pp. 15, figs. 3.)
Relation of mosaic to running out of potatoes in Minnesota. F. A. Krantz and G. R. Bisby. (Minnesota Sta. Bul. 197, pp. 31, figs. 20.)
Diseases of sweet potatoes. M. T. Cook and R. F. Poole. (New Jersey Stas. Circ. 123, pp. 24, figs. 18.)
Recent investigations on the control of three important field diseases of sweet potatoes. R. F. Poole. (New Jersey Stas. Bul. 365, pp. 39, figs. 10.)
Tobacco wildfire.—Preliminary report of investigations. G. H. Chapman and P. J. Anderson. (Massachusetts Sta. Bul. 203, pp. 67-81, pl. 1.)
The wheat bunt problem in Oregon. D. E. Stephens and H. M. Woolman. (Oregon Sta. Bul. 188, pp. 42, figs. 5.)
Septoria glume blotch of wheat. H. R. Rosen. (Arkansas Sta. Tech. Bul. 175, pp. 17, figs. 4.)

Fruit, nut, and flower diseases.

Orchard practice for the control of blister canker of apple trees. H. W. Anderson. (Illinois Sta. Circ. 258, pp 16, figs. 12.)
Apple blister canker and its control. W. O. Gloyer and J. D. Luckett. (New York State Sta. Bul. 485, pop. ed., pp. 12, figs. 8.)
A study of the control of crown gall on apple grafts in the nursery. I. E. Melhus and T. J. Maney. (Iowa Sta. Research Bul. 69, pp. 159-172.)
Pear and apple blight in Montana. D. B. Swingle. (Montana Sta. Circ. 98, pp. 10, figs. 3.)
Peach disease control. J. A. McClintock. (Georgia Sta. Bul. 139, pp. 30, figs. 6.)
Recent studies on peach yellows and little peach. M. A. Blake, M. T. Cook, and C. H. Connors. (New Jersey Stas. Bul. 356, pp. 62, pls. 2, figs. 28.)
The coffee leaf spot (*Stilbella flavida*) in Porto Rico. T. B. McClelland. (Porto Rico Sta. Bul. 28, pp. 12, pls. 4.)
Spraying experiments for the control of pecan scab. D. C. Neal. (Mississippi Sta. Bul. 203, pp. 14, figs. 9.)
Rust of Antirrhinum. W. L. Doran. (Massachusetts Sta. Bul. 202, pp. 39-66, pl. 1, figs. 2.)
The Botrytis blight of tulips. E. F. Hopkins. (New York Cornell Sta. Mem. 45, pp. 315-361, pl. 1, figs. 29.)

Vegetable diseases.

Bean anthracnose. M. F. Barrus. (New York Cornell Sta. Mem. 42, pp. 97-215, pls. 5, figs. 14.)
The yellows disease of cabbage in southwest Virginia. F. D. Fromme. (Virginia Sta. Bul. 226, pp. 9, figs. 5.)
A Phoma root rot of celery. C. W. Bennett. (Michigan Sta. Tech. Bul. 53, pp. 40, figs. 11.)
The Sclerotinia rot of celery. R. F. Poole. (New Jersey Stas. Bul. 359, pp. 27, figs. 17.)
Controlling downy mildew of lettuce. A. T. Erwin. (Iowa Sta. Bul. 196, pp. 305-328, figs. 8.)
Development and pathogenesis of the onion smut fungus. P. J. Anderson. (Massachusetts Sta. Tech. Bul. 4, pp. 99-133, figs. 6.)
Onion diseases and onion seed production. C. W. Edgerton. (Louisiana Stas. Bul. 182, pp. 20, figs. 9.)
Tomato mosiac. M. W. Gardner and J. B. Kendrick. (Indiana Sta. Bul. 261, pp. 24, figs. 13.)

Miscellaneous.

Plant disease and pest control. W. T. Horne and E. O. Essig. (California Sta. Circ. 227, pp. 69.)
Internal fungus parasites of agricultural seeds. C. C. Chen. (Maryland Sta. Bul. 240, pp. 79–110, figs. 22.)
Fungicidal action of formaldehyde. I. E. Melhus, J. C. Gilman, and J. B. Kendrick. (Iowa Sta. Research Bul. 59, pp. 355–397, figs. 6.)

105313—24——10

ENTOMOLOGY AND ZOOLOGY

Bees.

Winter care of bees in Wisconsin. H. F. Wilson. (Wisconsin Sta. Bul. 338, pp. 26, figs. 7.)
Diseases of bees in Michigan. R. H. Kelty. (Michigan Sta. Spec. Bul. 107, pp. 16, figs. 6.)

Field-crop insects.

The Mexican bean beetle. G. M. List. (Colorado Sta. Bul. 271, pp. 58, figs. 16.)
The larger cornstalk borer in Virgina. W. J. Phillips, G. W. Underhill, and F. W. Poos. (Virginia Sta. Tech. Bul. 22, pp. 30, figs. 13.)
The eelworm disease of red clover. R. H. Smith. (Idaho Sta. Bul. 130, pp. 14, figs. 6.)
Control of the potato leaf hopper. F. A. Fenton and A. Hartzell. (Iowa Sta. Circ. 77, pp. 4, figs. 4.)
Combat potato leaf hopper with Bordeaux. J. E. Dudley, jr., and H. F. Wilson. (Wisconsin Sta. Bul. 334, pp. 31, figs. 19.)
Rose bushes in relation to potato culture. E. M. Patch. (Maine Sta. Bul. 303, pp. 321–344, pl. 1.)
A meadow caterpillar. E. M. Patch. (Maine Sta. Bul. 302, pp. 309-320, pls. 2.)
The grass-feeding frog-hopper or spittle-bug. P. Garman. (Connecticut State Sta. Bul. 230, pp. 325–334, pls. 2, figs. 3.)
Grasshoppers and related insects. A. P. Morse. (Maine Sta. Pamphlet [541-6-21], pp. 6.)

Fruit insects.

The important orchard insects of Idaho and their control. R. H. Smith. (Idaho Sta. Circ. 23, pp. 8.)
Lepidoptera injurious to the apple in Pennsylvania. S. W. Frost. (Pennsylvania Sta. Bul. 169, pp. 16, figs. 6.)
Plant lice injurious to apple orchards.—III, The delayed dormant spray for the control of rosy and green apple aphids. F. Z. Hartzell and L. F. Strickland. (New York State Sta. Bul. 487, pp. 41, figs. 5.)
Apple aphids controlled with the delayed dormant spray. J. D. Luckett, F. Z. Hartzell, and L. F. Strickland. (New York State Sta. Bul. 487, pop. ed., pp. 8, figs. 2.)
Control of apple red bugs by dusting. P. J. Parrott, H. Glasgow, and G. F. MacLeod. (New York State Sta. Bul. 490. pp. 30, pls. 5.)
Dusting *v.* spraying for red bugs. J. D. Luckett, P. J. Parrott, H. Glasgow, and G. F. MacLeod. (New York State Sta. Bul. 490, pop. ed., pp. 8, pl. 1, fig. 1.)
A destructive bud worm of apple trees (*Haploa lecontei*). H. Garman. (Kentucky Sta. Circ. 25, pp. 11, figs. 5.)
Paradichlorobenzene (p-c-benzene) for controlling the peach-tree borer. A. Peterson. (New Jersey Stas. Circ. 126, pp. 11, figs. 7.)
Codling moth control for certain sections of Colorado. G. M. List and J. H. Newton. (Colorado Sta. Bul. 268, pp. 31, figs. 12.)
The codling moth in the Payette Valley. L. E. Longley. (Idaho Sta. Bul. 124, pp. 27, figs. 10.)
The green June beetle or fig eater. J. J. Davis and P. Luginbill. (North Carolina Sta. Appendix to Bul. 242, pp. 8, figs. 22.)
The life history of the oriental fruit moth in northern Virginia. L. A. Stearns. (Virginia Sta. Tech. Bul. 21, pp. 46, figs. 8.)
Spraying for San José scale. W. J. Baerg. (Arkansas Sta. Bul. 177, pp. 19, figs. 2.)
An explanation of recent failures in San José scale control. W. A. Ruth. (Illinois Sta. Circ. 252, pp. 4.)
The strawberry crown borer (*Tyloderma fragariae*). H. Garman. (Kentucky Sta. Circ. 27, pp. 27–34, figs. 2.)
Eastern strawberry louse. W. J. Baerg. (Arkansas Sta. Tech. Bul. 179, pp. 16, figs. 4.)

Vegetable insects.

Control of the cabbage maggot. L. G. Schermerhorn and C. H. Nissley. (New Jersey Stas. Circ. 138, pp. 4, figs. 2.)

The bionomics and control of the onion maggot. J. R. Eyer. (Pennsylvania Sta. Bul. 171, pp. 16, figs. 5.)

The onion thrips in Iowa. J. L. Horsfall and F. A. Fenton. (Iowa Sta. Bul. 205, pp. 53–68, figs. 11.)

The root maggot of radishes, turnips, cabbage, and related vegetables. R. H. Smith. (Idaho Sta. Circ. 24, pp. 3, figs. 2.)

Forest insects.

Description of eight new bark beetles (Ipidae) from Mississippi. M. W. Blackman. (Mississippi Sta. Tech. Bul. 10, pp. 16, figs. 2.)

The painted hickory borer. E. H. Dusham. (New York Cornell Sta. Bul. 407, pp. 171–203, figs. 2.)

Mosquitos and household insects.

A mosquito manual for use in New Jersey schools. (New Jersey Stas. Circ. 130, pp. 16, figs. 22.)

The mosquitos of New Jersey and their control. T. J. Headlee. (New Jersey Stas. Bul. 348, pp. 229, figs. 133.)

Mosquito survey of Mayaguez. W. V. Tower. (Porto Rico Sta. Circ. 20, pp. 10, pls. 4.)

The control of household insects. W. P. Flint. (Illinois Sta. Circ. 257, pp. 24, figs. 15.)

Stored products insects.

Insects infesting stored food products. R. N. Chapman. (Minnesota Sta. Bul. 198, pp. 76, figs. 58.)

Insect pests of stored grains and their control. M. H. Swenk. (Nebraska Sta. Circ. 15, pp. 14, figs. 9.)

Heat for control of cereal insects. W. H. Goodwin. (Ohio Sta. Bul. 354, pp. 18.)

Insecticides.

Insecticides and fungicides for farm and orchard crops in Massachusetts. E. B. Holland, A. I. Bourne, and P. J. Anderson. (Massachusetts Sta. Bul. 201, pp. IV + 37, pl. 1.)

Insecticides and fungicides for farm and orchard crops in Massachusetts. E. B. Holland, A. I. Bourne, and P. J. Anderson. (Massachusetts Sta. Bul. 201, pop. ed., pp. 16, pl. 1.)

The preparation of nicotine dust as an insecticide. R. E. Smith. (California Sta. Bul. 336, pp. 261–274.)

Miscellaneous.

The relation of the Kentucky species of Solidago to the period of activity of adult *Cyllene robiniae.* H. Garman. (Kentucky Sta. Research Bul. 231, pp. 22, figs. 6.)

Monograph of the North American species of Deraeocoris (Heteroptera, Niridæ). H. H. Knight. (Minnesota Sta. Tech. Bul. 1, pp. 75–210, figs. 47.)

Attachment of the abdomen to the thorax in Diptera. B. P. Young. (New York Cornell Sta. Mem. 44, pp. 255–306, figs. 77.)

The biology of *Ephydra subopaca* Loew. C. Ping. (New York Cornell Sta. Mem. 49, pp. 561–616, figs. 5.)

Annotated list of Halticini. A. B. Duckett. (Maryland Sta. Bul. 241, pp. 107–155.)

North American Ipidae of the subfamily Micracinae, with description of new species and genera. M. W. Blackman. (Mississippi Sta. Tech. Bul. 9, pp. 62, pls. 5.)

Typha insects: Their ecological relationships. P. W. Claassen. (New York Cornell Sta. Mem. 47, pp. 459–531, figs. 86.)

The crane flies of New York.—II. Biology and phylogeny. C. P. Alexander. (New York Cornell Sta. Mem. 38, pp. 691–1133, figs. 540.)

Horseflies and cattle. S. B. Doten. (Nevada Sta. Bul. 102, pp. 13, figs. 8.)

Miscellaneous—Continued.

The European pileworm.—A dangerous marine borer in Barnegat Bay, New Jersey. T. C. Nelson. (New Jersey Stas. Circ. 139, pp. 15, figs. 9.)

Control of the pocket gopher in California. J. Dixon. (California Sta. Bul. 340, pp. 337–350, figs. 5.)

The common hawks and owls of California from the standpoint of the rancher. J. Dixon. (California Sta. Circ. 236, pp. 17, figs.13.)

FOODS AND HUMAN NUTRITION

Vitamins and the daily diet. J. W. Read, S. Palmer, and L. Steer. (Arkansas Sta. Bul. 176, pp. 24.)

Wheat, flour, and bread. M. K. Corbould. (Ohio Sta. Bul. 350, pp. 185–219, pls. 6, figs. 12.)

How the farmer can save his sweet potatoes and ways of preparing for the table. G. W. Carver. (Alabama Tuskegee Sta. Bul. 38, pp. 23, figs. 4.)

Milk the best food. H. Steenbock and E. B. Hart. (Wisconsin Sta. Bul. 342, pp. 19, figs. 10.)

ANIMAL PRODUCTION

Feeds and nutrition.

Digestion experiments. G. S. Fraps. (Texas Sta. Bul. 291, pp. 16, figs. 2.)

Digestibility of the sugars, starches, pentosans, and proteids of some feeding stuffs. G. S. Fraps. (Texas Sta. Bul. 290, pp. 21, figs. 2.)

Studies in animal nutrition.—I, Changes in form and weight on different planes of nutrition. C. R. Moulton, P. F. Trowbridge, and L. D. Haigh. (Missouri Sta. Research Bul. 43, pp. 111, pl. 1, figs. 30.)

The influence of the plane of nutrition on the maintenance requirement of cattle. A. G. Hogan, W. D. Salmon, and H. D. Fox. (Missouri Sta. Research Bul. 51, pp. 48, pls. 3, figs. 5.)

The nutritive value of cattle feeds.—II, Oat by-products for farm stock. J. B. Lindsey and C. L. Beals. (Massachusetts Sta. Bul. 200, pp. 117–135; also pop. ed., pp. 10, figs. 2.)

The nutritive value of cattle feeds.—III, Dried apple pomace for farm stock. J. B. Lindsey, C. L. Beals, and J. G. Archibald. (Massachusetts Sta. Bul. 205, pp. 135–148.)

The relative growth-promoting value of the protein of coconut-oil meal, and of combinations of it with protein from various other feeding stuffs. L. A. Maynard and F. M. Fronda. (New York Cornell Sta. Mem. 50, pp. 621–633, figs. 4.)

Chamiza as an emergency feed for range cattle. L. Foster, J. L. Lantow, and C. P. Wilson. (New Mexico Sta. Bul. 125, pp. 27, figs. 11.)

Cattle feeding investigations.—Comparative value of silage for making beef. W. L. Blizzard. (Oklahoma Sta. Bul. 139, pp. 6.)

Sugar beet top silage. R. E. Neidig. (Idaho Sta. Circ. 17, pp. 4.)

Factors influencing quality and composition of sunflower silage. M. J. Blish. (Montana Sta. Bul. 141, pp. 22.)

Quality in sunflower silage. M. J. Blish. (Montana Sta. Circ. 96, pp. 7.)

The composition and feeding value of wheat by-products. G. S. Fraps. (Texas Sta. Bul. 282, pp. 42.)

Vitamins on the farm.—Their practical relation to livestock feeding. A. R. Lamb and J. M. Evvard. (Iowa Sta. Circ. 73, pp. 8, figs. 4.)

A study of the metabolism and respiratory exchange in poultry during vitamin starvation and polyneuritis. R. J. Anderson and W. L. Kulp. (New York State Sta. Tech. Bul. 88, pp. 22.)

The acid base balance in animal nutrition.—I, The effect of certain organic and mineral acids on growth, well-being, and reproduction of swine. II, Metabolism studies on the effect of certain organic and mineral acids on swine. A. R. Lamb and J. M. Evvard. (Iowa Sta. Research Bul. 70, pp. 174–192.)

The acid base balance in animal nutrition.—III, Effect of addition of alkalis to the ration on growth and well-being of swine. A. R. Lamb and J. M. Evvard. (Iowa Sta. Research Bul. 71, pp. 194–208, figs. 4.)

The utilization of calcium compounds in animal nutrition. (Ohio Sta. Bul. 347, pp. 99, figs. 2.)

Beef cattle.

Growing steers. E. L. Potter and R. Withycombe. (Oregon Sta. Bul. 182, pp. 15, fig. 1.)
Steer feeding experiments, 1920–21. C. W. Hickman, E. F. Rinehart, and A. W. Johnson. (Idaho Sta. Circ. 18, pp. 4.)
Feeding yearling steers. (Wyoming Sta. Circ. 17, pp. 4.)
Stocker cattle problems on the Cumberland plateau. C. A. Willson. (Tennessee Sta. Bul. 125, pp. 45–62, figs. 2.)
Homegrown feeds for range steers. F. A. Hays. (Wyoming Sta. Bul. 128, pp. 53–75, fig. 1.)
Cattle feeding.—XVII, Winter steer feeding, 1920–1921. J. H. Skinner and F. G. King. (Indiana Sta. Bul. 255, pp. 24, fig. 1; also pop. ed., pp. 8, fig. 1.)
Cattle-feeding investigations. 1920–21. C. W. McCampbell and H. B. Winchester. (Kansas Sta. Circ. 92, pp. 13, figs. 3.)
A comparison of corn silage and sorghum silage for fattening steers. E. S. Good, I. J. Horlacher, and J. C. Grimes. (Kentucky Sta. Bul. 233, pp. 61–89, figs. 8.)
A comparison of broken ear corn and shelled corn, fed with silage, for fattening steers. E. S. Good and L. J. Horlacher. (Kentucky Sta. Circ. 26, pp. 15–26, figs. 2.)
Feeding cottonseed and cottonseed products to range steers. E. B. Stanley. (Arizona Sta. Bul. 93, pp. 484–491, figs. 2.)
Wintering and summer fattening of steers in North Carolina. R. S. Curtis, F. T. Peden, and F. W. Farley. (North Carolina Sta. Bul. 243, pp. 20, figs. 4.)
Shelter and warm water for fattening steers. E. L. Potter and R. Withycombe. (Oregon Sta. Bul. 183, pp. 11, figs. 6.)
The trail of the short-grass steer.—The story of a Great Plains grazing trail. J. H. Shepperd. (North Dakota Sta. Bul. 154, pp. 8, figs. 8.)

Horses.

Feeding purebred draft fillies. J. L. Edmonds and W. G. Kammlade. (Illinois Sta. Bul. 235, pp. 329–360, figs. 9.)
Feeding farm work horses and mules. J. L. Edmonds and W. G. Kammlade. (Illinois Sta. Bul. 238, pp. 411–427, figs. 2.)

Sheep.

Sheep-feeding investigations.—X, Fattening western lambs, 1920–21. J. H. Skinner and C. M. Vestal. (Indiana Sta. Bul. 256, pp. 16, figs. 2; also pop. ed., pp. 8, figs. 2.)
Lamb-feeding experiments, 1920–21. C. W. Hickman, E. F. Rinehart, and A. W. Johnson. (Idaho Sta. Circ. 19, pp. 4.)
Lamb-feeding investigations, 1919–20. A. M. Paterson and H. B. Winchester. (Kansas Sta. Circ. 88, pp. 6, fig. 1.)
Native feeds for fattening lambs. F. A. Hays. (Wyoming Sta. Bul. 130, pp. 16, fig. 1.)
Grain sorghums *v.* corn for fattening lambs. J. M. Jones and R. A. Brewer. (Texas Sta. Bul. 285, pp. 23.)
Silage for fattening lambs. R. Withycombe and E. L. Potter. (Oregon Sta. Bul. 184, pp. 7, figs. 4.)
Sheep losses in Colorado feed lots.—I, Feeding experiments. G. H. Glover and I. E. Newsom. (Colorado Sta. Bul. 270, pp. 25.)

Swine.

Swine production. M. F. Grimes. (Pennsylvania Sta. Bul. 168, pp. 16, figs. 3.)
Swine-feeding investigations, 1919–20. E. F. Ferrin and H. B. Winchester. (Kansas Sta. Circ. 89, pp. 10, fig. 1.)
Hog-feeding experiments. J. I. Thompson and E. C. Voorhies. (California Sta. Bul. 342, pp. 371–396, fig. 1.)
Rations for pigs. J. W. Wilson and A. H. Kuhlman. (South Dakota Sta. Bul. 192, pp. 302–316, figs. 4.)
Supplements to corn for fattening swine. W. L. Robison. (Ohio Sta. Bul. 349, pp. 129–183, figs. 34.)

Swine—Continued.

Field peas for pork production. R. E. Gongwer. (Idaho Sta. Bul. 125, pp. 8, fig. 1.)
Rice bran for fattening hogs. D. W. Williams and O. E. McConnell. (Texas Sta. Bul. 286, pp. 15.)
Swine mineral mixtures. J. M. Evvard. (Iowa Sta. Circ. 70, pp. 2.)
Self-feeding swine. W. L. Robison. (Ohio Sta. Bul. 355, pp. 19–50, figs. 7.)

Poultry.

1920 and 1921 experiments with poultry. E. P. Clayton and J. P. Clayton. (Mississippi Sta. Bul. 204, pp. 8, figs. 2.)
La crianza de aves en Puerta Rico. H. C. Hendricksen. (Porto Rico Sta. Circ. 19, Spanish ed., pp. 22, figs. 14.)
Poultry experiments, observations, notes, and plans. R. H. Waite. Maryland Sta. Bul. 244, pp. 40, figs. 29.)
Methods of mating poultry. L. S. Dodson. (New Jersey Stas. Hints to Poultrymen, 10 (1921), No. 3, pp. 4, fig. 1.)
Practical points in poultry breeding. G. W. Hervey. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 9, pp. 4, fig. 1.)
Poultry-breeding contest. R. B. Thompson. (Arizona Sta. Circ. 41, pp. 4.)
Feeding experiments with laying pullets. A. G. Philips. (Indiana Sta. Bul. 258, pp. 28, figs. 9.)
Summer production in the laying pens. R. R. Hannas. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 8, pp. 4, fig. 1.)
Egg-laying characteristics of the hen. J. Dryden. (Oregon Sta. Bul. 180, pp. 96, figs. 26.)
Selecting laying hens. R. B. Thompson. (Arizona Sta. Circ. 39, pp. 8, figs. 2.)
High quality market eggs: Producing, handling, packing. G. H. Pound. (New Jersey Stas. Hints to Poultrymen, 10 (1921), No. 2, pp. 4, fig. 1.).
Culling, a practical plan to eliminate the nonproducing hen. W. H. Allen. (New Jersey Stas. Hints to Poultrymen, 9 (1921), No. 9, pp. 4, fig. 1.)
Finishing the pullets. W. P. Thorp, jr. (New Jersey Stas. Hints to Poultrymen, 9 (1921), No. 11, pp. 4, fig. 1.)
Report of egg-laying contests for 1921. R. R. Hannas. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 5, pp. 4.)
How to candle eggs. W. F. Schoppe. (Montana Sta. Circ. 97, pp. 19, figs. 2.)
Natural incubation and brooding. W. F. Schoppe. (Montana Sta. Circ. 103, pp. 8, figs. 3.)
Artificial incubation. J. E. Dougherty. (California Sta. Circ. 233, pp. 10, figs. 4.)
Poultry housing. J. Dryden. (Oregon Sta. Bul. 179, pp. 22, figs. 15.)
Sanitary practices on the poultry plant. W. C. Thompson and G. W. Hervey. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 4, pp. 4, fig. 1.)
Summer health means winter eggs. G. W. Hervey. (New Jersey Stas. Hints to Poultrymen, 9 (1921), No. 10, pp. 4.)
Monthly standards for New Jersey poultry farms. W. H. Allen. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 6, pp. 4.)
Control of poultry lice and mites. W. F. Schoppe. (Montana Sta. Circ. 95, pp. 8, figs. 2.)
The business possibilities of poultry keeping. W. C. Thompson. (New Jersey Stas. Hints to Poultrymen, 9 (1921), No. 12, pp. 4. fig. 1.)
Practical facts for the squab raiser. W. C. Thompson. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 7, pp. 4, fig. 1.)

Miscellaneous.

Report of progress on animal husbandry investigations in 1920. J. W. Cowen. (Maine Sta. Bul. 299, pp. 85–120, figs. 7.)
The effect on growth of breeding immature animals. F. B. Mumford. (Missouri Sta. Research Bul. 45, pp. 37, pls. 6.)
Dressing and cutting lamb and mutton on the farm. M. D. Helser. (Iowa Sta. Circ. 71, pp. 16, figs. 25.)
Dressing and cutting beef on the farm. M. D. Helser. (Iowa Sta. Circ. 72, pp. 23, figs. 30.)
Directions for the tanning and dressing of furs. J. Dixon. (California Sta. Circ. 237, pp. 5, figs. 3.)

DAIRYING AND DAIRY PRODUCTS

Dairy farming. J. B. Fitch. (Kansas Sta. Circ. 90, pp. 32, figs. 13.)
Studies of dairy cattle. J. J. Hooper. (Kentucky Sta. Research Bul. 234, pp. 91–161, figs. 24.)
Judging dairy cattle. G. C. Humphrey. Wisconsin Sta. Bul. 335, pp. 44, figs. 23.)
Advanced registry testing in Indiana. L. H. Fairchild. (Indiana Sta. Circ. 102, pp. 16, figs. 5.)
Studies in milk secretion.—IX, On the performance of the progeny of Holstein-Friesian sires. J. W. Gowen and M. R. Covell. (Maine Sta. Bul. 300, pp. 121–252, figs. 2.)
Studies in milk secretion.—XII, Transmitting qualities of Holstein-Friesian sires for milk yield, butterfat percentage, and butterfat. J. W. Gowen and M. R. Covell. (Maine Sta. Bul. 301, pp. 253–308, figs. 2.)
Dairy calves.—Consumption of food and gain by different breeds—general notes, feed and care. E. Brintnall. (Mississippi Sta. Bul. 200, pp. 16, fig. 1.)
Wintering dairy heifers. R. E. Hunt. (Virginia Sta. Bul. 225, pp. 15, figs. 5.)
Feeding dairy cattle. M. H. Keeney. (New Jersey Stas. Circ. 127, pp. 38, figs. 7.)
Feeding dairy cattle. T. M. Olson. (South Dakota Sta. Bul. 195, pp. 357–372, figs. 2.)
Feeding standards for milk production. W. B. Ellett, C. W. Holdaway, and W. G. Harris. (Virginia Sta. Tech. Bul. 23, pp. 52.)
Influence of condition on maintenance requirements of dairy cattle. A. C. McCandlish and W. G. Gaessler. (Iowa Sta. Research Bul. 60, pp. 403–420, figs. 6.)
The heavy feeding of milk cows is now profitable. H. A. Ross. (Illinois Sta. Circ. 250, pp. 2.)
A comparison of silage and soiling crops for summer milk production. A. C. McCandlish. (Iowa Sta. Bul. 201, pp. 8.)
Coconut meal as a feed for dairy cows and other livestock. F. W. Woll. (California Sta. Bul. 335, pp. 241–258.)
Preparation of corn for dairy cows. A. C. McCandlish and G. E. Weaver. (Iowa Sta. Bul. 195, pp. 297–304.)
Feeding blackstrap molasses to young calves. R. C. Calloway. (Louisiana Stas. Bul. 180, pp. 22, fig. 1.)
Blackstrap molasses for dairy cattle. E. Brintnall. (Mississippi Sta. Circ. 38, pp. 4.)
The production of clean milk. R. N. Davis. (Arizona Sta. Circ. 37, pp. 12, figs. 12.)
Effect of temperature of pasteurization on the creaming ability of milk. H. A. Harding. (Illinois Sta. Bul. 237, pp. 395–408, figs. 6.)
The measurement of the volume of cream on milk. H. A. Harding. (Illinois Sta. Circ. 249, pp. 16.)
Testing milk, cream, and skim milk for butterfat. J. C. Marquardt. (California Sta. Circ. 230, pp. 11, figs. 7.)
Milking machines.—VI, Leakage from the vacuum pipe line into the pail as a source of contamination of milk. R. S. Breed and J. W. Bright. (New York State Sta. Bul. 488, pp. 19, figs. 9.)
Milking machines.—VII, Further studies on methods of sterilization. A. H. Robertson, M. W. Finch, and R. S. Breed. (New York State Sta. Bul. 492, pp. 36.)
Leaky valves on milking machines contaminate milk. J. D. Luckett, R. S. Breed, and J. W. Bright. (New York State Sta. Bul. 488, pp. 8, figs. 8.)
Germ content of milk.—III, As influenced by visible dirt. H. A. Harding and M. J. Prucha. (Illinois Sta. Bul. 236, pp. 363–391, fig. 1.)
The relation between bacterial counts from milk as obtained by microscopic and plate methods. A. H. Robertson. (New York State Sta. Bul. 86, pp. 21, pls. 5.)
Variations in bacteria counts from milk as affected by media and incubation temperature. G. C. Supplee, W. A. Whiting, and P. A. Downs. (New York Cornell Sta. Mem. 43 pp., 217–247.)
The microscopic study of bacteria in cheese. G. J. Hucker. (New York State Sta. Tech. Bul. 87, pp. 11, pl. 1.)
The type of lactic acid produced by starters and by organisms isolated from them. B. W. Hammer. (Iowa Sta. Research Bul. 65, pp. 115–128.)

The relation between the volatile and total acidity in starters and in cultures of *S. lacticus*. W. A. Cordes and B. W. Hammer. (Iowa Sta. Research Bul. 66, pp. 130–136.)

Volatile acid production of *S. lacticus* and the organisms associated with it in starters. B. W. Hommer. (Iowa Sta. Research Bul. 63, pp. 59–96. + [3].)

The colorimetric hydrogen-ion determination as a means of studying biological changes in dairy products. L. H. Cooledge. (Michigan Sta. Tech. Bul. 52, pp. 20, figs. 4.)

Does carbon dioxide in carbonated milk and milk products destroy bacteria? M. J. Prucha, J. M. Brannon, and A. S. Ambrose. (Illinois Sta. Circ. 256, pp. 8.)

Sources of the flavor in butter. B. W. Hammer. (Iowa Sta. Research Bul. 67, pp. 139–144.)

Burnt or caramel flavor of dairy products. B. W. Hammer and W. A. Cordes. (Iowa Sta. Research Bul. 68, pp. 147–156.)

A study of brown glass milk bottles, with reference to their use in preventing abnormal flavors. B. W. Hammer and W. A. Cordes. (Iowa Sta. Research Bul. 64, pp. 99–111.)

VETERINARY SCIENCE

Preliminary rat virus investigations. (North Dakota Sta. Bul. 155, pp. 4.)

Poisoning from *Bacillus botulinus*.—Cause, prevention, treatment. Z. N. Wyant. (Michigan Sta. Circ. 47, pp. 8.)

Actinomycosis (lump jaw, big jaw, and wooden tongue) in cattle. J. W. Connaway. (Missouri Sta. Bul. 186, pp. 15, figs. 9.)

Infectious abortion in cattle. L. F. Rettger, G. C. White, and L. M. Chapman. (Connecticut Storrs Sta. Bul, 108, pp. 59–88.)

The comparative pathogenicity of several strains of *Bacterium abortus* (Bang). I. F. Huddleson. (Michigan Sta. Tech. Bul. 55, pp. 14.)

Preliminary notes on parasites found in ruminants at municipal abattoir, Baton Rouge, La. G. Dikmans. (Louisiana Stas. Tech. Bul. 183, pp. 13, figs. 12.)

Studies in the diseases of the reproductive organs of cattle. E. T. Hallman. (Michigan Sta. Tech. Bul. 54, pp. 23, pls. 6.)

Internal parasites affecting sheep and goats.—Causes, life history, symptoms, and treatments. D. H. Bennet. (Texas Sta. Circ. 28, pp. 3–16, figs. 9.)

Stomach worms in sheep. J. E. Guberlet. (Oklahoma Sta. Bul. 137, pp. 16, figs. 5.)

Some pests of Ohio sheep. D. C. Mote. (Ohio Sta. Bul. 356, pp. 51–79, figs. 18.)

Infectious abortion in swine. J. W. Connaway, A. J. Durant, and H. G. Newman. (Missouri Sta. Bul. 187, pp. 28, figs. 12.)

Swine dysentery. R. A. Whiting, L. P. Doyle, and R. S. Spray. (Indiana Sta. Bul. 257, pp. 15, figs. 10.)

The hog louse, *Haematopinus suis* Linne, its biology, anatomy, and histology. L. Florence. (New York Cornell Sta. Mem. 51, pp. 637–743, figs. 9.)

A study of poultry diseases. W. C. Thompson and L. S. Dodson. (New Jersey Stas. Bul. 363, pp. 61, figs. 20.)

Tuberculosis of poultry. C. H. Werkman and W. M. Gibbs. (Idaho Sta. Bul. 126, pp. 12, figs. 6.)

The principal stock-poisoning plants of Oregon. W. E. Lawrence. (Oregon Sta. Bul. 187, pp. 3–43, pls. 2, figs. 9.)

Death camas (*Zygadenus paniculatus* and *Zygadenus venenosus*), plants poisonous to sheep and cattle. C. E. Fleming, N. F. Peterson, et al. (Nevada Sta. Bul. 101, pp. 31, figs. 13.)

The poison parsnip or water hemlock (*Cicuta occidentalis*), a plant deadly to livestock in Nevada. C. E. Fleming, N. F. Peterson, et al. (Nevada Sta. Bul. 100, pp. 23, pl. 1, figs. 8.)

AGRICULTURAL ENGINEERING

The Colorado River and Arizona's interest in its development. G. E. P. Smith. (Arizona Sta. Bul. 95, pp. 527–546, figs. 2.)

Farm drainage. W. L. Powers and W. Cretcher. (Oregon Sta. Bul. 178, pp. 47, figs. 33.)

Drainage in the Mesilla Valley of New Mexico. D. W. Bloodgood. (New Mexico Sta. Bul. 129, pp. 37, figs. 22.)

Pump drainage of the University of Wisconsin marsh. G. R. B. Elliott, E. R. Jones, and O. R. Zeasman. (Wisconsin Sta. Research Bul. 50, pp. 32, figs. 15.)
The adobe milkhouse. C. B. Brown. (Arizona Sta. Circ. 38, pp. 4, figs. 3.)
Handy equipment for swine raising. W. G. Kaiser and J. M. Evvard. (Iowa Sta. Circ. 69, pp. 47, figs. 43.)
Hog houses for Nebraska. O. W. Sjogren and I. D. Wood. (Nebraska Sta. Circ. 14, pp. 20, figs. 30.)
Sunshine and sanitation for hog houses. W. A. Foster and J. M. Evvard. (Iowa Sta. Bul. 194, pp. 257–296, figs. 45.)
Poultry houses. W. F. Schoppe. (Montana Sta. Circ. 100, pp. 23, figs. 9.)
Farm-poultry buildings. J. G. Halpin, J. B. Hayes, and O. R. Zeasman. (Wisconsin Sta. Bul. 336, pp. 31, figs. 18.)
Poultry-house equipment. W. H. Allen. (New Jersey Stas. Hints to Poultrymen, 10 (1921), No. 1, pp. 4, fig. 1.)
Use of wooden constructed fire-heated hotbeds for production of sweet potato plants. C. L. Isbell and W. D. Kimbrough. (Alabama College Sta. Bul. 217, pp. 6, figs. 3.)
The effect of alkali on Portland cement. (Wyoming Sta. Circ. 16, pp. 4, figs. 2.)

RURAL ECONOMICS AND SOCIOLOGY

Home economics exhibits for county and community fairs. M. Wilkerson. (Illinois Sta. Circ. 247, pp. 24, figs. 8.)
Home economics extension service in Illinois. J. L. Bane. (Illinois Sta. Circ. 248, pp. 18, pl. 1.)
The costs of crop production in Missouri, 1921. B. H. Frame. (Missouri Sta. Bul. 190, pp. 15, figs. 2.)
Farm costs and relative profitableness of seven crops, Twin Falls County, Idaho, 1919–20. B. Hunter and S. B. Nuckols. (Idaho Sta. Research Bul. 2, pp. 24.)
Cost of producing truck in Copiah County, 1921. J. N. Lipscomb and M. E. Andrews. (Mississippi Sta. Circ. 39, pp. 4.)
Costs, profits, and practices of the can-house tomato industry in New Jersey. F. App and A. G. Waller. (New Jersey Stas. Bul. 353, pp. 85, figs. 18.)
The relative cost of making logs from small and large timber. D. Bruce. (California Sta. Bul. 339, pp. 317–333, fig. 1.)
Thousands sign for cooperative marketing. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 8 (1921), No. 46, pp. 8.)
Local cooperative potato marketing in Minnesota. J. D. Black, F. Robotka, and P. L. Miller. (Minnesota Sta. Bul. 195, pp. 88, figs. 7.)
Cooperative livestock shipping in Iowa in 1920. E. G. Nourse and C. W. Hammans. (Iowa Sta. Bul. 200, pp. 401–436, figs. 3.)
Marketing livestock given special attention. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 9 (1922) No. 47, pp. 8.)
Sell wool cooperatively. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 9 (1922), No. 52, pp. 5.)
Study manner and time to market hogs for best results. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 9 (1922), No. 50, pp. 8.)
The cost of producing milk. H. B. Munger. (Iowa Sta. Bul. 197, pp. 337–352.)
Studies in city milk distribution. S. J. Brownell. (Michigan Sta. Spec. Bul. 111, pp. 24, fig. 1.)
An experiment in improving the milk supply of a city milk plant. L. H. Cooledge and O. T. Goodwin. (Michigan Sta. Spec. Bul. 112, pp. 16, figs. 3.)
Creamery bookkeeping. M. Mortensen. (Iowa Sta. Circ. 68, pp. 20, figs. 11.)
An economic study of farm tractors in New York. W. I. Myers. (New York Cornell Sta. Bul. 405, pp. 51–134, figs. 12.)
Graphic presentation of statistics of farm products. H. E. Selby. (Montana Sta. Circ. 99, pp. 46, pl. 1, figs.48.)
A graphical presentation of the financial phases of feeding experiments. H. H. Mitchell. (Illinois Sta. Bul. 234, pp. 271–327, pl. 1, figs. 15.)
Farm-management studies.—Lessons from irrigated farms in the Billings region. E. L. Currier. (Montana Sta. Circ. 101, pp. 36, figs. 28.)
Iowa farm-management surveys in Blackhawk, Grundy, and Tama Counties. H. D. Munger. (Iowa Sta. Bul. 198, pp. 355–375b.)

Farm tenantry in the United States. W. B. Bizzell. (Texas Sta. Bul. 278, pp. 408.)
Methods of renting land in Ohio. J. I. Falconer. (Ohio Sta. Bul. 348, pp. 101–130, figs 6.)
The Federal farm-loan system. I. Wright. (Illinois Sta. Circ. 259, pp. 20.)
The farmer's credit. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 9 (1922), No. 48, pp. 9.)
Farmer must solve his own credit problems. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 9 (1922), No. 51, pp. 6.)
Farm development studies in northern Minnesota. C. G. Worsham and A. Boss. (Minnesota Sta. Bul. 196, pp. 47, figs. 4.)
Rural primary groups. J. H. Kolb. (Wisconsin Sta. Research Bul. 51, pp. 81, figs. 22.)
French Creek as a rural community. A. J. Dadisman. (West Virginia Sta. Bul. 176, pp. 23, figs. 27.)

REPORTS, PERIODICALS, REGULATORY PUBLICATIONS, AND PUBLICATION LISTS

Reports.

Report of the Alaska Agricultural Experiment Stations, 1920. C. C. Georgeson et al. pp. V+75, pls. 7.
Report of the director of the agricultural experiment station, 1921. C. M. Haring. (Rpt. Col. Agr. and Agr. Expt. Sta., Univ. California, 1921, pp. 15–166.)
The thirty-fourth annual report of the [Colorado] Agricultural Experiment Station, 1921. C. P. Gillette et al. pp. 43.
Forty-fourth annual report of the Connecticut [State] Agricultural Experiment Station, New Haven, Conn., for the year 1920. E. H. Jenkins et al. pp. XVI+377, pls. 20, figs. 114.
Report of the director for the year ending October 31, 1921. E. H. Jenkins. (Connecticut State Sta. Bul. 232, pp. 18.)
Annual report of the director for the fiscal year ending June 30, 1920. C. A. McCue et al. (Delaware Sta. Bul. 126, pp. 28.)
Annual report of the director for the fiscal year ending June 30, 1921. C. A. McCue et al. (Delaware Sta. Bul. 129, pp. 30.)
Thirty-fourth annual report, Georgia Experiment Station, for the year 1921. H. P. Stuckey. pp. 26, figs. 6.
Report of the Guam Agricultural Experiment Station, 1920. C. W. Edwards et al. pp. 79, pls. 8.
Report of the Hawaii Agricultural Experiment Station, 1920. J. M. Westgate et al. pp. 72, pls. 10, figs. 2.
Work and progress of the agricultural experiment station for the year ended December 31, 1921. E. J. Iddings. (Idaho Sta. Bul. 129, pp. 15.)
Thirty-fourth annual report of the Purdue University Agricultural Experiment Station, Lafayette, Indiana, for the year ending June 30, 1921. G. I. Christie. pp. 56, figs. 31.
Annual report for fiscal year ending June 30, 1920, Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts. C. F. Curtiss and W. H. Stevenson. pp. 64.
Director's report [Kansas Agricultural Experiment Station], 1919–20. F. D. Farrell. pp. 99.
Thirty-second annual report of the Kentucky Agricultural Experiment Station for the year 1919, Part II. pp. 372+29–38+III, pls. 4, figs. 12.
Thirty-third annual report of the Agricultural Experiment Station of the University of Kentucky for the year 1920, Part I. T. Cooper. pp. 49.
Thirty-third annual report of the agricultural experiment stations of the Louisiana State University and Agricultural and Mechanical College for 1921. W. R. Dodson. pp. 32.
The thirty-fourth annual report of the University of Maryland Agricultural Experiment Station, 1921. H. J. Patterson. pp. XIX+186, figs. 38.
Thirty-third annual report of the Massachusetts Agricultural Experiment Station [1920], Parts I and II. S. B. Haskell et al. pp. 60a+144, pl. 1, figs. 14.
Thirty-third annual report of the Experiment Station of the Michigan Agricultural College for the year ending June 30, 1920. R. S. Shaw et al. pp. 227–700, figs. 79.

Reports—Continued.

Twenty-ninth annual report of the [Minnesota] Agricultural Experiment Station, 1921. R. W. Thatcher et al. pp. 117.

Mississippi Agricultural Experiment Station, thirty-fourth annual report for the fiscal year ending June 30, 1921. J. R. Ricks et al. pp. 56.

One year's work [of] the agricultural experiment station for the year July 1, 1920, to June 30, 1921. F. B. Mumford et al. (Missouri Sta. Bul. 189, pp. 64, figs. 18.)

Biennial reports of the Missouri State Fruit Experiment Station, 1915–1920. P. Evans, F. W. Faurot, et al. Rpts. 1915–16, pp. 7; 1917–18, pp. 11; 1919–20, pp. 12, figs. 7.

Twenty-seventh annual report [Montana Agricultural Experiment Station] for the fiscal year ending June 30, 1920. F. B. Linfield et al. pp. 52.

Annual report of the board of control [Nevada Agricultural Experiment Station] for the fiscal year ending June 30, 1920. pp 16.

Annual report of the board of control [Nevada Agricultural Experiment Station] for the fiscal year ending June 30, 1921. pp. 20, figs. 2.

Report of the New Hampshire Agricultural Experiment Station for the biennium ending June 30, 1920. (New Hampshire Sta. Bul. 198, pp. 22.)

Report of the director of the New Hampshire Agricultural Experiment Station for the year ending June 30, 1921. J. C. Kendall. (New Hampshire Sta. Bul. 203, pp. 31, figs. 2.)

Forty-first annual report of the New Jersey State Agricultural Experiment Station and the thirty-third annual report of the New Jersey Agricultural Experiment Station for the year ending June 30, 1920. J. G. Lipman et al. pp. XXXII+610, pls. 23, figs. 63.

Thirty-first annual report, Agricultural Experiment Station of the New Mexico College of Agriculture and Mechanic Arts, 1920. F. Garcia. pp. 53, figs. 9.

Thirty-second annual report, Agricultural Experiment Station of the New Mexico College of Agriculture and Mechanic Arts, 1921. F. Garcia. pp. 48.

Thirty-fourth annual report of the New York State College of Agriculture at Cornell University and of the Agricultural Experiment Station, 1921. A. R. Mann. pp. 97+[5].

Thirty-ninth annual report of the New York [State] Agricultural Experiment Station for the year 1920. W. H. Jordan et al. pp. VII+586, pls. 21, figs. 37.

Fortieth annual report [New York State Agricultural Experiment Station] with the director's report for 1921. R. W. Thatcher. pp. 40.

Forty-fourth annual report of the North Carolina Agricultural Experiment Station for the fiscal year ending June 30, 1921. B. W. Kilgore et al. pp. 80.

Fortieth annual report of the Ohio Agricultural Experiment Station for the year ended June 30, 1921. C. G. Williams. (Ohio Sta. Bul. 353, pp. XXX+[5], fig. 1.)

Two years of research (for the biennium ending June 30, 1921). (Pennsylvania Sta. Bul. 170, pp. 32.)

Annual report of the Porto Rico Agricultural Experiment Station, 1920. D. W. May et al. pp. 39, pls. 6.

Thirty-third annual report of the director of the Agricultural Experiment Station of the Rhode Island State College, [1920]. B. L. Hartwell. pp. 15.

Thirty-fourth annual report of the South Carolina Experiment Station of the Clemson Agricultural College for the year ended June 30, 1921. H. W. Barre. pp. 55, figs. 19.

South Dakota Agricultural Experiment Station, annual report of the director for the fiscal year ending June 30, 1921. J. W. Wilson et al. pp. 37.

Thirty-third annual report [Texas Agricultural Experiment Station], 1920. B. Youngblood. pp. 80, figs. 36.

Thirty-first annual report for the year ending June 30, 1921. E. C. Johnson et al. (Washington Col. Sta. Bul. 167, pp. 64.)

New pages in farming.—Annual report of the director, 1920–21. H. L. Russell and F. B. Morrison. (Wisconsin Sta. Bul. 339, pp. 43, figs. 40.)

Thirty-first annual report of the University of Wyoming Agricultural Experiment Station, 1921. A. D. Faville et al. pp. 109–140, fig. 1.

Report of the Cranberry Station for 1919 and 1920. H. J. Franklin. (Massachusetts Sta. Bul. 206, pp. 149–168.)

Reports—Continued.

Special report of the Upper Peninsula Experiment Station. D. L. McMillan and G. W. Putnam. (Michigan Sta. Spec. Bul. 110, pp. 40, figs. 26.)
Report of the Northwest Experiment Station, Crookston [Minnesota], 1920. C. G. Selvig et al. pp. 114, figs. 20.
Report of the Northeast Demonstration Farm and Experiment Station, Duluth [Minnesota], 1920. M. J. Thompson. pp. 28, figs. 5.
Report of West Central Experiment Station, Morris [Minnesota], 1920. P. E. Miller. pp. 36.
Report from Holly Springs Branch Experiment Station for 1921. C. T. Ames. (Mississippi Sta. Bul. 202, pp. 29, figs. 5.)
Report from South Mississippi Branch Experiment Station for 1921. E. B. Ferris and F. B. Richardson. (Mississippi Sta. Bul. 201, pp. 20.)
Report of the Hettinger Substation for the years 1919 and 1920. U. J. Downey. (North Dakota Sta. Bul. 150, pp. 15, figs. 5.)
Twenty-first report of the State Entomologist for 1921. W. E. Britton. (Connecticut State Sta. Bul. 234, pp. 111–204, pls. 16, figs. 6.)
Report of the tree protection examining board for the biennial period ending June 30, 1921. W. E. Britton et al. Miscellaneous notes. E. H. Jenkins. (Connecticut State Sta. Bul. 231, pp. 337–356.)
Digging up facts for New Hampshire farms. J. C. Kendall. (New Hampshire Sta. Bul. 199, pp. 30, figs. 19.)
Thirty years of agricultural experiments in Utah. F. S. Harris and N. I. Butt. (Utah Sta. Circ. 46, pp. 64, fig. 1.)

Periodicals.

Quarterly Bulletin, Michigan Agricultural Experiment Station—
Vol. 3 (1921), No. 4, pp. 117–148, figs. 11.
Vol. 4 (1921), No. 1, pp. 29, figs. 6; No. 2, pp. 35–66, figs 11; (1922), No. 3, pp. 71–113, figs. 13; No. 4, pp. 117–160, figs. 9.
Monthly Bulletin, Ohio Agricultural Experiment Station—
Vol. 6 (1921), No. 7–8, pp. 97–128, figs. 7; No. 9–10, pp. 129–160, figs. 9; No. 11–12, pp. 161–191, figs. 16.
Vol. 7 (1922), No. 1–2, pp. 40, figs. 8; No. 3–4, pp. 42–72, figs. 9.
Bimonthly Bulletin, Western Washington Experiment Station, Puyallup, Wash.—
Vol. 9 (1921), No. 3, pp. 33–48, figs. 5; No. 4, pp. 49–64, figs. 6; No. 5, pp. 65–80; (1922), No. 6, pp. 81–100, figs. 4; No. 7, pp. 101–124, fig. 1.
Vol. 10 (1922), No. 1, pp. 22, figs. 8.

Regulatory Publications—Fertilizers.

Fertilizer report for 1921. E. H. Jenkins and E. M. Bailey. (Connecticut State Sta. Bul. 233, pp. 21–109.)
Commercial fertilizers. E. G. Proulx et al. (Indiana Sta. Bul 253, pp. 71, figs. 2.)
Analyses of commercial fertilizers. H. E. Curtis, H. R. Allen, and R. H. Ridgell. (Kentucky Sta. Bul. 230, pp. 193–320.)
Commercial fertilizers, 1921. J. M. Bartlett. (Maine Sta. Off. Insp. 101, pp. 61–80.)
Inspection of commercial fertilizers. H. D. Haskins, L. S. Walker, and A. M. Clarke. (Massachusetts Sta. Control Ser. Bul. 14, pp. 92.)
Inspection of commercial fertilizers. H. D. Haskins, L. S. Walker, and R. W. Swift. (Massachusetts Sta. Control Ser. Bul. 16, pp. 39.)
Fertilizer analyses. A. J. Patten, O. B. Winter, M. L. Grettenberger, and P. O'Meara. (Michigan Sta. Bul. 291, pp. 109.)
Inspection of commercial fertilizers for 1921. H. R. Kraybill, T. O. Smith, and C. P. Spaeth. (New Hampshire Sta. Bul. 201, pp. 16.)
Analyses of commercial fertilizers, fertilizer supplies, and home mixtures, 1921. C. S. Cathcart. (New Jersey Stas. Bul. 358, pp. 55.)
Analyses of commercial fertilizers and ground bone. Analyses of agricultural lime. C. S. Cathcart. (New Jersey Stas. Bul. 361, pp. 52.)
Fertilizer registrations for 1922. C. S. Cathcart. (New Jersey Stas. Bul. 364, pp. 29.)
Inspection of commercial fertilizers. P. H. Wessels. (Rhode Island Sta. Ann. Fert. Circ., 1921, pp. 12.)

Regulatory Publications—Fertilizers—Continued.

Analyses of commercial fertilizers. R. N. Brackett and H. M. Stackhouse. (South Carolina Sta. Bul. 208, pp. 48.)
Commercial fertilizers in 1920–21. G. S. Fraps and S. E. Asbury. (Texas Sta. Bul. 280, pp. 22.)

Regulatory Publications—Feeding Stuffs.

Commercial feeding stuffs. E. G. Proulx et al. (Indiana Sta. Bul. 260, pp. 16, figs. 2.)
Commercial feeding stuffs. J. D. Turner, H. D. Spears, and E. L. Jackson. (Kentucky Sta. Bul. 235, pp. 165–301.)
Commercial feeding stuffs, 1920–21. J. M. Bartlett. (Maine Sta. Off. Insp. 100, pp. 21–60.)
Inspection of commercial feedstuffs. P. H. Smith and E. M. Bradley. Massachusetts Sta. Control Ser. Bul. 15, pp. 34.)
Commercial feeding stuffs. A. J. Patten, O. B. Winter, M. L. Grettenberger, and P. O'Meara. (Michigan Sta. Bul. 292, pp. 63.)
Inspection of commercial feeding stuffs. H. R. Kraybill, T. O. Smith, and C. P. Spaeth. (New Hampshire Sta. Bul. 200, pp. 43.)
Analyses of commercial feeding stuffs and registrations for 1921. C. S. Cathcart. (New Jersey Stas. Bul. 354, pp. 68.)
A study of the composition of official samples of feeding stuffs and mixtures collected in 1920. L. L. Van Slyke. (New York State Sta. Bul. 482, pp. 23.)
Inspection of commercial feeds. P. H. Wessels and F. P. Gross, jr. (Rhode Island Sta. Ann. Feed Circ., 1921, pp. 12.)
Commercial feeding stuffs. B. Youngblood. (Texas Sta. Bul. 281, pp. 204.)

Regulatory Publications—Seeds.

Experiment station regulations under Arizona uniform seed law. (Arizona Sta. Circ. 40, pp. 8.)
How to comply with the Indiana seed law. E. G. Proulx. (Indiana Sta. Circ. 105, pp. 8, figs. 4.)
Seed analyses, 1913–1921. L. H. Pammel and C. M. King. (Iowa Sta. Bul. 203, pp. 27–43.)
Commercial agricultural seeds, 1921. Insecticides and fungicides, 1920 and 1921. W. J. Morse. (Maine Sta. Off. Insp. 102, pp. 81–100.)
Work of the seed inspection laboratory for the year 1920. F. S. Holmes. (Maryland Sta. Bul. 243, pp. 167–186.)
Results of seed tests for 1921. M. G. Eastman. (New Hampshire Sta. Bul. 202, pp 24.)
Results of seed and legume inoculant inspection for 1921. J. G. Fiske. (New Jersey Stas. Bul. 360, pp. 37.)
State laws concerning the sale of seeds and legume inoculants. J. G. Fiske. (New Jersey Stas. Circ. 137, pp. 15, fig. 1.)

Regulatory Publications—Miscellaneous.

Commercial fertilizers, commercial feeding stuffs. agricultural seed. J. L. Hills, C. H. Jones, G. F. Anderson, and A. S. Lutman. (Vermont Sta. Bul. 220, pp. 32.)
Commercial fertilizers, commercial feeding stuffs, agricultural seed. J. L. Hills, C. H. Jones, G. F. Anderson, and A. S. Lutman. (Vermont Sta. Bul. 223, pp. 30.)
Foods and drugs. J. M. Bartlett. (Maine Sta. Off. Insp. 99, pp. 20.)
Analyses of materials sold as insecticides and fungicides during 1921. C. S. Cathcart and R. L. Willis. (New Jersey Stas. Bul. 357, pp. 22.)
Seventh annual report of the creamery license division, 1921. T. H. Broughton. (Indiana Sta. Circ. 103, pp. 16, figs. 2.)
Creamery inspection in New Jersey. F. C. Button. (New Jersey Stas. Circ. 129, pp. 16, figs. 4.)
Inspection of lime products used in agriculture. H. D. Haskins, L. S. Walker, and R. W. Swift. (Massachusetts Sta. Control Ser. Bul. 17, pp. 8, fig. 1.)
Fourth and fifth annual reports for the years 1919–1920 by the Oklahoma State Livestock Registry Board. (Oklahoma Sta. Circ. 47, pp. 155, figs. 4.)

Regulatory Publications—Miscellaneous—Continued.

Stallion enrollment.—X, Report of stallion enrollment work for the year 1921 with lists of stallions and jacks enrolled. (Indiana Sta. Circ. 104, pp. 72, fig. 1.)

Publication lists.

A list of books for the farmer's library. (Illinois Sta. Circ. 251, pp. 27.)
Publications available for free distribution. (Idaho Sta. Circ. 20, pp. 2.)